Air Quality Impact Assessment for the Proposed Mining Activities on ML 197 for the Omitiomire Copper Project, Khomas Region, Namibia

Project done for **Environmental Compliance Consultancy (ECC)**

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Revision Record

Version	Date	Comments
Rev 0	November 2023	For internal review
Rev 1	November 2023	For client review
Rev 2	January 2024	Incorporation of clients comments
Rev 3	February 2024	Inclusion of Appendix C

Abbreviations

AERMIC	AMS/EPA Regulatory Model Improvement Committee
AQG	Air Quality Guidelines
AQIA	Air Quality Impact Assessment
AQMP	Air Quality Management Plan
AQO	Air Quality Objectives
AQSRs	Air Quality Sensitive Receptors
ASTM	American Society for Testing and Materials standard method
CERC	Cambridge Environmental Research Consultants
CO	Carbon monoxide
CO_2	Carbon dioxide
Cu	Copper
EC	European Community
ECC	Environmental Compliance Consultancy
EHS	Environmental, Health and Safety
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
FEL	Front-end-loaders
GHG	Greenhouse gas
GIIP	Good International Industry Practice
HC	Hydrocarbon
IFC	International Finance Corporation
IT	Interim target
LMo	Obukhov length
LOM	Life of mine
ML	Mining license
NAAQS	National Ambient Air Quality Standards (South Africa)
NACA	National Association for Clean Air
NDCR	National Dust Control Regulations (South Africa)
NO_2	Nitrogen dioxide
NOx	Oxides of nitrogen
NPI	Australian National Pollutant Inventory
O_3	Ozone
PAH	Polycyclic aromatic hydrocarbons
PM	Particulate Matter
PM_{10}	Particulate matter with an aerodynamic diameter of less than 2.5 µm (thoracic particles)
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of less than 10 µm (respirable particles)
ROM	Run-of-Mine
SA	South African
SACNASP	South African Council for Natural Scientific Professions
SEMP	Strategic Environmental Management Plan
SO_2	Sulfur dioxide
TSP	Total Suspended Particulates
US	United States
VKT/day	Vehicle kilometres travelled per day
VOC	Volatile organic compound

WBG	World Bank Group
WHO	World Health Organisation
WRDs	Waste rock dumps
WRF	The Weather Research and Forecasting (WRF) Model

Units

°C	Degree Celsius
km	kilometre
lb	pound
m	metres
$mg/m^2/day$	milligram per metre squared per day
Mtpa	million tons per annum
t	ton
tpa	tons per annum
$\mu g/m^3$	microgram per cubic metre
%	percent

Glossary

Air pollution: means any change in the composition of the air caused by smoke, soot, dust (including fly ash), cinders, solid particles of any kind, gases, fumes, aerosols and odorous substances.

Atmospheric emission: means any emission or entrainment process emanating from a point, non-point or mobile sources that result in air pollution.

Averaging period: This implies a period of time over which an average value is determined.

Dust: Solid materials suspended in the atmosphere in the form of small irregular particles, many of which are microscopic in size.

Frequency of Exceedance: A frequency (number/time) related to a limit value representing the tolerated exceedance of that limit value, i.e. if exceedances of limit value are within the tolerances, then there is still compliance with the standard.

Particulate Matter (PM): These comprise a mixture of organic and inorganic substances, ranging in size and shape and can be divided into coarse and fine particulate matter. The former is called Total Suspended Particulates (TSP), whilst PM_{10} and $PM_{2.5}$ fall in the finer fraction referred to as Inhalable particulate matter.

TSP: Total suspended particulates refer to all airborne particles and may have particle sizes as large as 150 µm, depending on the ability of the air to carry such particles. Generally, suspended particles larger than 75 to 100 micrometre (µm) do not travel far and deposit close to the source of emission.

PM_{10}: Thoracic particulate matter is that fraction of inhalable coarse particulate matter that can penetrate the head airways and enter the airways of the lung. PM_{10} consists of particles with a mean aerodynamic diameter of 10 µm or smaller, and deposit efficiently along the airways. Particles larger than a mean size of 10 µm are generally not inhalable into the lungs. These PM_{10} particles are typically found near roadways and dusty industries.

$PM_{2.5}$: Respirable particulate fraction is that fraction of inhaled airborne particles that can penetrate beyond the terminal bronchioles into the gas-exchange region of the lungs. Also known as fine particulate matter, it consists of particles with a mean aerodynamic diameter equal to or less than 2.5 µm ($PM_{2.5}$) that can be inhaled deeply into the lungs. These particles can be directly emitted from sources such as forest fires, or they can form when gases emitted from power plants, industries and automobiles react in the air.

Point sources: are discrete, stationary, identifiable sources of emissions that release pollutants to the atmosphere (International Finance Corporation (IFC), 2007).

Vehicle entrainment: This is the lifting and dropping of particles by the rolling wheels leaving the road surface exposed to strong air current in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed.

Executive Summary

Craton Mining and Exploration (Pty) Ltd holds the mining licence 197 (ML 197) over farm Omitiomire, located 140 km northeast of Windhoek (by road) and approximately 39 km south of Hochfeld, in the Khomas Region of Namibia.

Exploration undertaken since 2007 has resulted in a mineral resource of approximately 105.5 million tonnes at 0.59% Copper (Cu). Most of the deposit is in the form of copper sulphides, specifically chalcocite, containing high proportions of copper and low proportions of iron. The copper sulphides have been oxidised near the surface to approximately 40 m, and at a depth next to major fractures and fault lines. The oxidised copper ores, mainly malachite, make up approximately 10% of the total mineralisation.

An air quality assessment is required as part of the Environmental Impact Assessment (EIA) for the Omitiomire Copper Project which will consist of the operation of the open pit copper mine, heap leach and related electrowinning facilities and the production of cathode copper (hereafter referred to as the project). Airshed Planning Professionals (Pty) Ltd was appointed by Environmental Compliance Consultancy (ECC) to undertake an air quality impact assessment for the proposed project.

The main objective of the investigation was to quantify the potential air quality impacts resulting from the proposed activities on the surrounding environment and human health. As part of the air quality assessment, a good understanding of the regional climate and local dispersion potential of the site is necessary and subsequently an understanding of existing sources of air pollution in the region and the current and potential future activities resulting in air quality related impacts.

The scope of work (SoW) included the review of technical information and legislative context relevant to Namibia. A baseline assessment was required to get an understanding of the receiving environment, looking at existing sources of air pollution and the status of air quality within the region, as well as sensitive receptors in the form of human settlements. Modelled meteorological data for a three-year period (1 January 2020 to 31 December 2022) was used to determine the dispersion potential of the site, which influences the spreading and removal of air pollution. To determine the potential impacts from the proposed project operations, an emissions inventory had to be established accounting for all sources of air pollution associated with the mining activities (mining, and processing operations). Emissions were based on the process description and mine layout plan as provided. The AERMOD dispersion model was used to simulate the expected impacts from these emission sources, with the simulated particulate matter ground level concentrations and dustfall rates screened against the applicable air quality objectives (AQOs) to determine the significance of the proposed project on the receiving environment. Once the significance of these impacts has been established, the main contributing sources could be identified, and mitigation measures defined to ensure reduced impacts from these activities.

Baseline Characterisation

The main findings from the baseline assessment can be summarised as follows:

- The main sources likely to contribute to cumulative particulate impact are vehicle entrainment on unpaved road surfaces and wind erosion of open areas.
- The wind field is dominated by winds from the north-east.
- The closest communities are located more than 30 km from the project. The closest potential air quality sensitive receptors (AQSRs) to the project are farmsteads ~2.5 km to the east and ~3.5 km to the south of the mine boundary.
- Measured dust fallout for the period July 2022 to September 2023 was on average 70 mg/m²/day across all sites over the study area, with no exceedances of the residential or industrial dustfall AQOs.

- The main pollutant of concern in the region is particulate matter (PM) (i.e., total suspended particulates (TSP); inhalable particulate matter with diameter of less than 10 µm (PM_{10}) and thoracic particulate matter with diameter of less than 2.5 µm ($PM_{2.5}$)) resulting from vehicle entrainment on the roads (paved, unpaved and treated surfaces) and windblown dust. Gaseous pollutants such as sulfur dioxide (SO_2), oxides of nitrogen (NO_x), carbon monoxide (CO) and carbon dioxide (CO_2) would result from vehicles and combustion sources, but these are expected to be at low concentrations due to the few sources in the region.
- Sources of atmospheric emissions in the vicinity of the proposed project include:
    - Windblown dust: Windblown particulates from natural exposed surfaces, mine waste facilities, and product stockpiles can result in significant dust emissions with high particulate concentrations near the source locations, potentially affecting both the environment and human health. Windblown dust from natural exposed surfaces in and at the project is only likely to result in PM emissions under high wind speed conditions (>10 m/s), and since recorded wind speeds did not exceed 10 m/s, this source is likely to be of low significance.
    - Vehicle entrainment on paved and unpaved roads
    - Regional transport of pollutants: regional-scale transport of mineral dust and ozone (due to vegetation burning) from the north of Namibia is a significant contributing source to background PM concentrations.

Impact Assessment

The findings from the impact assessment can be summarised as follows:

- **Construction** normally comprises a series of different operations including land clearing, topsoil removal, road grading, material loading and hauling, stockpiling, grading, bulldozing, compaction, etc., with PM the main pollutants of concern from these activities. The extent of dust emissions would vary substantially from day to day depending on the level of activity, the specific operations, and the prevailing meteorological conditions, and how close these activities are to AQSRs. Due to the intermittent nature of construction operations, the emissions are expected to have a varying impact depending on the level of activity. With mitigation measures in place these impacts are expected to be low.
- **Operational Phase:**
    - Emissions quantified for the proposed project were restricted to fugitive releases (non-point releases) with particulates the main pollutant of concern. Gaseous emissions (i.e., SO_2, NO_x, CO and volatile organic compounds (VOCs)) will primarily result from diesel combustion. The gaseous impacts are expected to be localised.
    - Both unmitigated and mitigated scenarios were modelled. Mitigation that was applied was based on design mitigation measures provided, which included the following:
        - Surface haul roads: water sprays resulting in 75% control efficiency (CE);
        - Surface haul roads: chemical suppressants resulting in 90% CE;
        - Crushing and screening of run-of-mine (ROM) (primary; secondary and tertiary): resulting in 50% CE from water sprays to keep ore wet.
        - Drilling activities: fabric filters resulting in 99% CE.
    - Dispersion modelling results for unmitigated project operations indicate off-site exceedances of the AQOs for $PM_{2.5}$, PM_{10} at the closest AQSRs (i.e., ~2.5 km to the east and ~3.5 km to the south of the mine boundary).

- Dispersion modelling results for mitigated project operations indicate no off-site exceedances of the AQOs for $PM_{2.5}$, PM_{10} at the closest AQSRs.
- Maximum dust deposition due to unmitigated and mitigated project operations does not indicate exceedances of AQOs at the closest off-site AQSRs. Cumulative air quality impacts could not be assessed since no background PM_{10} and $PM_{2.5}$ data are available. The localised PM_{10} and $PM_{2.5}$ impacts from the proposed project modelling results indicate the potential for low regional cumulative impacts, and only high cumulative impacts in the immediate vicinity of the mine. Off-site impacts are likely to be managed with proper mitigation measures in place.

- **Closure** operations are likely to include demolishing existing structures, scraping and moving surface material to cover the remaining exposed surfaces (i.e., waste rock dumps (WRDs)) and contouring of the surface areas. The impacts are expected to be similar to that of construction operations – potentially small but harmful impacts at nearby receptors, depending on the level of activity but low impacts with mitigation measures in place. **Post-closure** operations, likely to include vegetation cover maintenance, would result in very low air quality related impacts.

Conclusion

The proposed project is likely to result in increased $PM_{2.5}$ and PM_{10} ground level in the immediate vicinity of the mine and impacts can be reduced by applying appropriate mitigation measures. The dispersion modelling results indicate that the $PM_{2.5}$ and PM_{10} AQOs may be exceeded at AQSRs off-site for unmitigated project operations. For mitigated project operations, $PM_{2.5}$ and PM_{10} AQOs are not exceeded at off-site AQSRs. Dustfall rates are likely to be within AQO at off-site AQSRs throughout the life of the project, with gaseous concentrations (SO_2, NO_2 and CO) expected to result in low air quality impacts.

It is the specialist's opinion that the proposed project could be authorised provided strict enforcement of mitigation measures and the tracking of the effectiveness of these measures to ensure the lowest possible off-site impacts.

Recommendations

Based on the findings from the air quality impact assessment for the project following recommendations are included:

- Construction and closure phases:
  - Air quality impacts during construction would be reduced through basic control measures such as limiting the speed of haul trucks; limit unnecessary travelling of vehicles on untreated roads; and applying dust-a-side on regularly travelled, unpaved sections.
  - When haul trucks need to use public roads, the vehicles need to be cleaned of all mud and the material transported must be covered to minimise windblown dust.
- Operational phases:
  - For the control of vehicle entrained dust a CE of 90% on unpaved surface roads through the application of chemical surfactants is recommended.
  - In controlling dust from crushing and screening operations, it is recommended that water sprays be applied to keep the ore wet, to achieve a CE of up to 50%.
- Air Quality Monitoring:
  - It is recommended that the current dustfall monitoring network be continued. The dustfall units must be maintained and the monthly dustfall results used as indicators to tract the effectiveness of the applied mitigation measures. Dustfall collection should follow the ASTM method.
  - It is further recommended that the dustfall monitoring network be supplemented by periodic ambient PM_{10} and $PM_{2.5}$ monitoring to determine whether the AQO are being met.

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1 INTRODUCTION

Craton Mining and Exploration (Pty) Ltd holds the mining licence 197 (ML 197) over farm Omitiomire, located 140 km northeast of Windhoek (by road) and approximately 39 km south of Hochfeld, in the Khomas Region of Namibia.

Exploration undertaken since 2007 has resulted in a mineral resource of approximately 81.4 million tonnes at 0.6% Copper (Cu). Most of the deposit is in the form of copper sulphides, specifically chalcocite, containing high proportions of copper and low proportions of iron. The copper sulphides have been oxidised near the surface to approximately 40 m, and at a depth next to major fractures and fault lines. The oxidised copper ores, mainly malachite, make up approximately 6% of the total mineralisation.

An air quality assessment is required as part of the Environmental Impact Assessment (EIA) for the Omitiomire Copper Project which will consist of the operation of the open pit copper mine, heap leach and related electrowinning facilities and the production of cathode copper (hereafter referred to as the project). Airshed Planning Professionals (Pty) Ltd was appointed by Environmental Compliance Consultancy (ECC) to undertake an air quality impact assessment for the proposed project.

The location of the project on Farm Omitiomire within ML 197, Khomas Region, Namibia is shown in Figure 1-1.

1.1 Purpose/Objective

The main objective of the investigation is to quantify the potential impacts resulting from the proposed activities on the surrounding environment and human health. As part of the air quality assessment, a good understanding of the regional climate and local dispersion potential of the site is necessary and subsequently an understanding of existing sources of air pollution in the region.

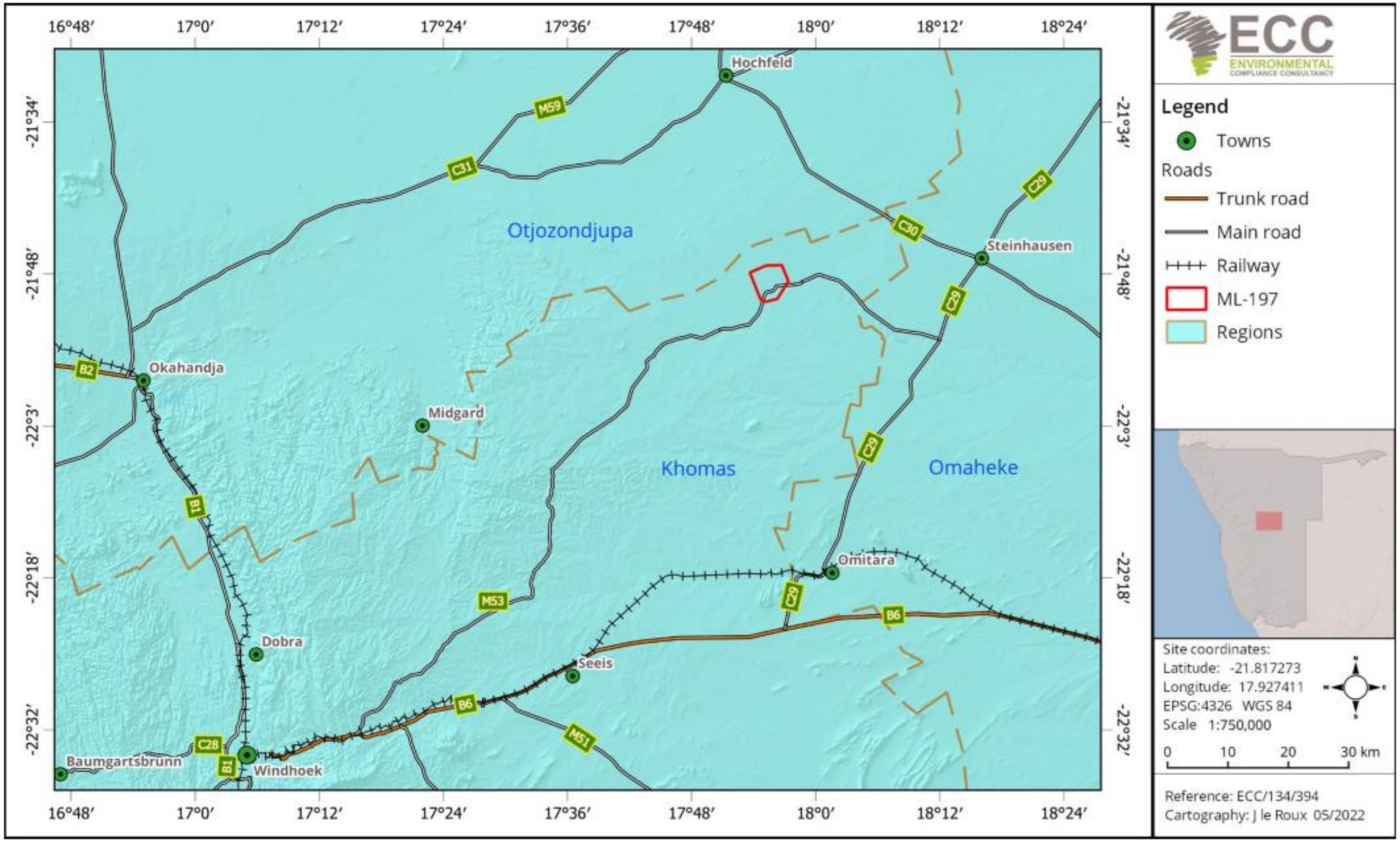

Figure 1-1: Location of the Omitiomire Copper Project

1.2 Terms of Reference/ Scope of Work

The baseline assessment includes a study of the receiving environment by referring to:

- A study of legal requirements pertaining to air quality – applicable international legal guidelines and limits and dust control regulations.
- Desktop review of all available project and associated data.
- A study of atmospheric dispersion potential by referring to available on-site weather records for a period of at least one year (required for dispersion modelling) or modelled weather data where on-site data is not available.
    - Details on the physical environment i.e., meteorology (atmospheric dispersion potential).
    - Identification of existing air pollution sources (other mines; industries; commercial operations, etc.).
    - Identification of air quality sensitive receptors (AQSRs), including any nearby residential dwellings in the vicinity of the mine.
    - Any freely available ambient air quality data, specifically particulate matter (PM).
- An impact assessment, including:
    - Identify all current sources of air pollution in the area.
    - The compilation of a comprehensive emissions inventory including the identification and quantification of all emissions associated with the proposed mining (open pit, hauling and processing operations).
    - Atmospheric dispersion modelling to simulate ambient air pollutant concentrations and dustfall rates from the project activities.
    - The screening of simulated ambient pollutant concentration levels and dust fallout against ambient air quality guidelines and standards.
- Assessment of the potential air quality impacts on human health and the environment.
- The identification and recommendation of suitable mitigation measures and monitoring requirements.
- The preparation of a comprehensive specialist air quality impact assessment (AQIA) report.

1.3 Deliverables

At the core of the study is the provision of a mathematical tool (i.e., the dispersion model) that credibly describes the fluxes and dispersion of air emissions from the project through the incorporation of meteorological and emission configuration complexities.

The final deliverables are simulated ground level air concentrations and total dust deposition rates provided as isopleths superimposed on base maps of the study area.

1.4 Specialist Details

1.4.1 Statement of Independence

Airshed is an independent consulting firm with no interest in the project other than to fulfil the contract between the client and the consultant for delivery of specialised services as stipulated in the terms of reference.

1.4.2 Competency Profiles

RG von Gruenewaldt (MSc (Meteorology), BSc, Pr. Sci Nat.)

Reneé von Gruenewaldt is a Registered Professional Natural Scientist (Registration Number 400304/07) with the South African Council for Natural Scientific Professions (SACNASP) and a member of the National Association for Clean Air (NACA).

Following the completion of her bachelor's degree in atmospheric sciences in 2000 and honours degree (with distinction) with specialisation in Environmental Analysis and Management in 2001 at the University of Pretoria, her experience in air pollution started when she joined Environmental Management Services (now Airshed Planning Professionals) in 2002. Reneé von Gruenewaldt later completed her master's degree (with distinction) in Meteorology at the University of Pretoria in 2009.

Reneé von Gruenewaldt became partner of Airshed Planning Professionals in September 2006. Airshed Planning Professionals is a technical and scientific consultancy providing scientific, engineering and strategic air pollution impact assessment and management services and policy support to assist clients in addressing a wide variety of air pollution related risks and air quality management challenges.

She has extensive experience on the various components of air quality management including emissions quantification for a range of source types, simulations using a range of dispersion models, impacts assessment and health risk screening assessments. Reneé has been the principal air quality specialist and manager on several Air Quality Impact Assessment projects between 2006 to present and her project experience range over various countries in Africa, providing her with an inclusive knowledge base of international legislation and requirements pertaining to air quality.

A comprehensive curriculum vitae of Reneé von Gruenewaldt is provided in Appendix A.

The declaration of independence for Reneé von Gruenewaldt is provided in Appendix B.

1.5 Project Description

With the focus of this assessment on air quality impacts from the proposed project operations on the surrounding environment, the subsequent discussion is intended to provide an indication of the likely source activities associated with the different phases of the project and to guide planning around the monitoring network (i.e., which pollutants to focus on). Air pollution associated with opencast mining activities include air emissions emitted during the construction-, operational-, closure- and post-closure phases.

The construction phase will include the establishment of required mining infrastructure and associated facilities such as workshops, maintenance areas, stores, wash bays, lay-down areas, fuel handling and storage area, offices, change houses, etc. Activities that would result in air pollution during the construction phase are listed Table 1-1-1.

Table 1-1: Construction activities resulting in air pollution

Activity	Associated pollutants
Handling and storage area for construction materials (paints, solvents, oils, grease) and waste	PM[a] and fumes (Volatile Organic Compounds (VOCs))
Power and water supply infrastructure	Sulfur dioxide (SO_2); oxides of nitrogen (NOx); carbon monoxide (CO); carbon dioxide (CO_2)[b]; PM
Clearing and other earth moving activities	Mostly PM, gaseous emissions from earth moving equipment (SO_2; NOx; CO; CO_2)
Stockpiling topsoil and sub-soil	Mostly PM, gaseous emissions from front-end-loaders (FEL) (SO_2; NOx; CO; CO_2)
Foundation excavations	Mostly PM, gaseous emissions from excavators (SO_2; NOx; CO; CO_2)
Opening and backfill of material	Mostly PM, gaseous emissions from trucks and equipment (SO_2; NOx; CO; CO_2)
Establishing access roads (scraping and grading)	Mostly PM, gaseous emissions from trucks and equipment (SO_2; NOx; CO; CO_2)
Digging of foundations and trenches	Mostly PM, gaseous emissions from diggers (SO_2; NOx; CO; CO_2)
Delivery of materials – storage and handling of material	Mostly PM, gaseous emissions from trucks (SO_2; NOx; CO; CO_2)
General building/construction activities including, amongst others: mixing of concrete; operation of construction vehicles and machinery; refuelling of machinery; civil, mechanical and electrical works; painting; grinding; welding; etc.	Mostly PM, gaseous emissions from construction vehicles and machinery (SO_2; NOx; CO; CO_2)

Notes: [a] PM comprises a mixture of organic and inorganic substances, ranging in size and shape and can be divided into coarse and fine PM. Total Suspended Particulates (TSP) represents the coarse fraction >10µm, with PM with an aerodynamic diameter of less than 10µm (PM_{10}) and PM with an aerodynamic diameter of less than 2.5µm ($PM_{2.5}$) falling into the finer inhalable fraction. TSP is associated with dust fallout (nuisance dust) whereas PM_{10} and $PM_{2.5}$ are considered a health concern.
[b] CO_2 is a greenhouse gas (GHG).

Project activities during the operation phase that are likely to result in pollutants to air are listed in Table 1-2.

Table 1-2: Operational activities resulting in air pollution

Activity		Associated pollutants
Haulage of materials (ore and waste rock)		PM from road surfaces and windblown dust from trucks, gaseous emissions from truck exhaust (PM, SO_2; NOx; CO; CO_2)
Waste rock dumps (WRDs)		PM from tipping and windblown dust, gaseous emissions from truck exhaust (PM, SO_2; NOx; CO; CO_2)
Heap leach pad		
Ore Stockpiles		
Processing Plant	Crushing and Screening	PM
	Loading from Stockpiles	Mostly PM, gaseous emissions from machinery (PM, SO_2; NOx; CO; CO_2)

Closure and post-closure activities typically include rehabilitation of the site infrastructure – demolition of infrastructure and vegetation of WRDs. These activities mainly result in PM emissions with gaseous emissions from equipment and trucks.

1.6 Project Approach and Methodology

The approach to, and methodology followed in the completion of tasks as part of the scope of work are provided in Table 1-3.

Table 1-3: Project Approach and Methodology

Task	Activity	Description	Report Section
Legal Review	A study of legal requirements pertaining to air quality in Namibia – ambient air quality standards and guidelines; dust control regulations and emission limits and guidelines.	Namibian Atmospheric Pollution Prevention Ordinance (No. 11 of 1976) International air quality criteria referenced, include: • World Health Organisation (WHO); • World Bank Group (WBG); • International Finance Corporation (IFC); and • South Africa (SA) air quality legislation.	Section 2
Baseline Assessment	Physical environmental parameters that influence the dispersion of pollutants in the atmosphere include: • land cover, and • meteorology.	Modelled meteorological data from January 2020 to December 2022 was used for the assessment.	Section 3.2
	Identification of existing air pollution sources.	Likely sources of potential air quality pollution include, but are not limited to, windblown dust and vehicle emissions.	Section 3.4
	Identification of AQSRs, including any nearby residential dwellings and proposed receptors (temporary or permanent workers accommodation site(s)) near the mine.	A map of all the potential AQSRs is provided.	Section 3.1
Impact Assessment	The compilation of an emissions inventory incl. the identification and quantification of all emissions associated with the proposed project operations.	Construction operations will include the development of the mining infrastructure. Pollutants quantified are limited to PM (TSP, PM_{10} and $PM_{2.5}$) and gaseous emissions (SO_2, NO_2 and CO). Use is made of process descriptions, mining rates and infrastructure maps to quantify activity emissions through the application of emissions factors and emission equations as published by the United States Environmental Protection Agency (US EPA) and Australian National Pollutant Inventory (NPI).	Section 4.1
	Atmospheric dispersion simulations of all pollutants (PM_{10}, $PM_{2.5}$ and dust fallout) for the operations reflecting highest daily and annual average concentrations due to routine emissions from the project operations.	Use was made of US EPA AERMOD atmospheric dispersion modelling suite.	Section 4.2

Task	Activity	Description	Report Section
	Dispersion modelling results and compliance evaluation for the different scenarios of the Operational phase. Construction, Closure and Decommissioning phases are assessed qualitatively.	Compliance is assessed by comparing modelled ambient PM ($PM_{2.5}$ and PM_{10}) concentrations and dustfall rates to the relevant national and international ambient air quality standards and dustfall regulations.	Section 4.3
	Air quality impact assessment	The impact significance is evaluated against the adopted Air Quality Objectives (AQO).	Section 4.3
	The identification of air quality management and mitigation measures based on the findings of the compliance and impact assessment.	Practical mitigation and optimisation measures that can be implemented effectively to reduce or enhance the significance of impacts were identified.	Section 5

An information requirements list was sent to ECC at the onset of the project. In response to the request, the following information was supplied:

- Layout maps;
- Material throughputs;
- Truck capacities;
- Number of drill holes per day and blast area per blast; and,
- Process descriptions.

1.7 Assumptions, Exclusions and Limitations

The main assumptions, exclusions and limitations are summarised below:

- Meteorological and Ambient Data:
  - Modelled meteorological data for the period January 2020 to December 2022 was used for the assessment as measured data with adequate data availability was not available for the site.
- Emissions:
  - The quantification of sources of emission was restricted to the project activities only. Although other background sources were identified, such as emissions from roads, these could not be quantified and did not form part of the scope of work.
  - Emissions were based on the process description and mine layout plan as provided. The maximum ore and waste throughput was utilised to quantify emissions.
  - Routine emissions for the proposed operations were simulated.
- Impact Assessment:
  - Impacts due to the operational phase were assessed quantitatively, whilst the construction, closure and decommissioning phases were assessed qualitatively due to the limited information available.
  - The impact assessment was limited to airborne particulate (including TSP, PM_{10} and $PM_{2.5}$). Gaseous emissions from vehicle exhaust were not modelled since impacts from these sources are usually localized and unlikely to exceed health screening limits outside the proposed mining right area.
  - Dust deposition rates were calculated using the estimated TSP concentrations and a deposition velocity of 3.62 cm/s as reported by Zhu et al (2016) for dry daytime conditions. It should be noted that this referenced deposition velocity is for PM_{10}. It is thus assumed that the PM_{10} deposition velocity is an average and that larger particles would fall out faster and finer particles would take longer to fallout.
  - There will always be some degree of uncertainty in any geophysical model, but it is desirable to structure the model in such a way to minimize the total error. A model represents the most likely outcome of an ensemble of experimental results. The total uncertainty can be thought of as the sum of three components: the uncertainty due to errors in the model physics; the uncertainty due to data errors; and the uncertainty due to stochastic processes (turbulence) in the atmosphere. Nevertheless, dispersion modelling is generally accepted as a necessary and valuable tool in air quality management.

2 Legal Overview

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. Air quality guidelines and standards are based on benchmark concentrations that normally indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Benchmark concentrations could therefore be based on health effects, such as SO_2 or carcinogenic consequences, such as benzene.

Air quality guidelines and standards are normally given for specific averaging or exposure periods and are evaluated as the observed air concentration expressed as a fraction of a benchmark concentration. A standard, as opposed to a benchmark concentration only, is a set of instructions which include a limit value and may contain a set of conditions to meet this limit value. Standards are normally associated with a legal requirement as implemented by the country's relevant authority; however, organisations such as the World Bank Group (WBG) International Finance Corporation (IFC) and private companies also issue standards for internal compliance. The benchmark concentrations issued by the World Health Organisation (WHO), on the other hand, are not standards, but rather guidelines that may be considered for use as limit values in standards.

A common condition included in a standard is the allowable frequency of exceedances of the limit value. The frequency of exceedances recognises the potential for unexpected meteorological conditions coupled with emission variations that may result in outlier air concentrations and would normally be based on a percentile, typically the 99^{th} percentile.

Standards are normally issued for criteria pollutants, i.e., those most commonly emitted by industry including SO_2, NO_2, CO, PM_{10} and $PM_{2.5}$, but may also include secondary pollutants such as ozone (O_3). Some countries include other pollutants, specifically when these are considered to be problematic emissions.

In addition to ambient air quality standards or guidelines, emission limits aim to control the amount of pollution from a point source[1]. Emissions to air should be avoided or controlled according to Good International Industry Practice (GIIP) applicable to the specific industry sector (IFC, 2007a).

Namibia does not have air quality guidelines or limits and reference is usually made to international ambient air quality guidelines and standards. The WHO is widely referenced, as well as countries in the region who have air quality standards. As part of the Air Quality Management Plan (AQMP) developed for the Strategic Environmental Management Plan (SEMP) update, ambient guidelines for PM_{10} and $PM_{2.5}$ were determined to provide the necessary performance indicators for mines and industries within the Erongo Region. These guidelines are regarded applicable to all mining operations in Namibia since these guidelines were adopted as Air Quality Objectives (AQO) in the Best Practice Guide for the Mining Sector in Namibia (see Section 2.1.1).

2.1 Namibian Legislation

The Atmospheric Pollution Prevention Ordinance (No. 11 of 1976) deals with the following:

Part I	:	Appointment and powers of officers;
Part II	:	Control of noxious or offensive gases;
Part III	:	Atmospheric pollution by smoke;
Part IV	:	Dust control;
Part V	:	Pollution of the atmosphere by gases emitted by vehicles;

[1] Point sources are discrete, stationary, identifiable sources of emissions that release pollutants to the atmosphere (IFC, 2007).

Part IV : General provisions; and
Schedule 2: Scheduled processes.

The Ordinance does not include any ambient air standards with which to comply, but opacity guidelines for smoke are provided under Part III. It is implied that the Director[2] provides air quality guidelines for consideration during the issuing of Registration Certificates, where Registration Certificates may be issued for "Scheduled Processes" which are processes resulting in noxious or offensive gases and typically pertain to point source emissions. To our knowledge no Registration Certificates have been issued in Namibia. However, an Environmental Clearance Certificate is required for any activity entailing a scheduled process as referred to in the Atmospheric Pollution Prevention Ordinance, 1976.

Also, the Ordinance defines a range of pollutants as noxious and offensive gases, but no ambient air quality guidelines or standards or emission limits are provided for Namibia.

Part II of the Ordinance pertains to the regulation of noxious or offensive gases. The Executive Committee may declare any area a *controlled area* for the purpose of this Ordinance by notice in the Official Gazette. Any scheduled process carried out in a *controlled area* must have a current registration certificate authorising that person to carry on that process in or on that premises.

The published Public and Environmental Health Act 1 of 2015 provides "a framework for a structured uniform public and environmental health system in Namibia; and to provide for incidental matters". The act identifies health nuisances, such as chimneys sending out smoke in quantities that can be offensive, injurious, or dangerous to health and liable to be dealt with.

2.1.1 Best Practice Guide for the Mining Sector in Namibia

A Best Practice Guide for the Mining Sector in Namibia was published in July 2020 (NCE, 2020). The document serves as a guiding framework during all mining phases to effectively assess aspects such as environmental and social impacts.

The report lists air quality as an environmental risk. It provides examples of sources and activities that would result in particulate and gaseous emissions and gives guidance on management and control of these source activities. Aspects relevant to the project can be summarised as follows:

- Section 3 provides requirements for Baseline Studies where air quality is listed as one of the most important aspects where background conditions of dust, gaseous and nuisance emissions and in some cases fumes and odours are required. Dust and gaseous emissions require immediate monitoring, as well as the establishment of a network of meteorological measuring points. Dust requires the monitoring of PM, in PM_{10}–format, but the monitoring program may require simultaneous measurement of TSP or $PM_{2.5}$ as well.
- Applicable ambient air quality guidelines are listed in Section 3 of the report. It states that Namibia does not have ambient air quality standards or guidelines and references published by the WBG, the WHO, and the European Community (EC). The South African (SA) National Ambient Air Quality Standards (NAAQS) are also referenced.
- Recommendations in Section 3 include: Dust Management Plans for all operational sites (mines, exploration sites and quarries); annual reporting of dust fall levels and PM_{10} concentrations to the authorities; dust suppression at construction sites (as well as annual reporting on dust mitigation measures); update and improvement of the current

[2] *Director* means the Director of Health Services of the Administration, and, where applicable, includes any person who, in terms of any authority granted to him under section 2(2) or (3) of the Ordinance.

emissions inventory; establishing a monitoring regime to enhance source apportionment of PM concentrations and sodium content; and continuation with PM_{10} and meteorological monitoring.

- Section 4 indicates that once mines are operational, an air quality management plan is essential for dealing with issues that can potentially have an adverse impact on operations. In addition to dust, an air quality plan needs to incorporate the management of emissions (release of pollutants and particulates) and fumes as well. All mines must, as a minimum requirement of an air quality management plan, manage dust.
- Requirements for air quality monitoring during the operational phase is provided.
- The report further provides guidance on closure and maintenance where management and monitoring of erosion is one of the essential aspects.

2.2 International Criteria

Typically, when no local ambient air quality criteria exist, or are in the process of being developed, international criteria are referenced. This serves to provide an indication of the severity of the potential impacts from proposed activities. The most widely referenced international air quality criteria are those published by the WBG, the WHO, and the EC. The South African (SA) National Ambient Air Quality Standards (NAAQS) are also referenced since it is regarded representative indicators for Namibia due to the similar environmental and socio-economic characteristics between the two countries.

2.2.1 WHO Air Quality Guidelines

Air Quality Guidelines (AQGs) were published by the WHO in 1987 and revised in 1997. Since the completion of the second edition of the AQGs for Europe, which included new research from low-and middle-income countries where air pollution levels are at their highest, the WHO has undertaken to review the accumulated scientific evidence and to consider its implications for its AQGs. The result of this work is documented in *'Air Quality Guidelines – Global Update 2005'* in the form of revised guideline values for selected criteria air pollutants, which are applicable across all WHO regions (WHO, 2005). The ITs and WHO AQGs have been updated recently (WHO, 2021) following a much stronger body of evidence to show how air pollution affects different aspects of health at even lower concentrations than previously understood.

Given that air pollution levels in developing countries frequently far exceed the recommended WHO AQGs, interim target (IT) levels were included in the updates. These are more lenient than the WHO AQGs with the purpose to promote steady progress towards meeting the WHO AQGs (WHO, 2005) (WHO, 2021). There are two to four interim targets depending on the pollutant, starting at WHO interim target-1 (IT-1) as the most lenient and IT-3 or IT-4 as more stringent targets before reaching the AQGs. The 24-hour SA NAAQS are, for instance, in line with IT-1 for SO_2 and IT-3 for PM_{10} and IT-4 for $PM_{2.5}$. It should be noted that the WHO permits a frequency of exceedance of 1% per year (3 to 4 days per year) for 24-hour average PM_{10} and $PM_{2.5}$ concentrations. These are provided in Table 2-1 for pollutants considered in this study.

2.2.2 SA National Ambient Air Quality Standards

NAAQSs for SA were determined based on international best practice for SO_2, NO_2, $PM_{2.5}$, PM_{10}, O_3, CO, Pb and benzene. These standards were published in the Government Gazette on 24 of December 2009 and included a margin of tolerance (i.e. frequency of exceedance) and with implementation timelines linked to it. SA NAAQSs for $PM_{2.5}$ were published on 29 July 2012. As mentioned previously, SA NAAQS closely follow WHO interim targets, which are targets for developing countries, for $PM_{2.5}$, PM_{10} and SO_2. The SA NAAQS for ambient NO_2 concentrations is equivalent to the WHO AQG. SA NAAQSs referred to in this study are also given in Table 2-1.

Table 2-1: International assessment criteria for criteria pollutants

Pollutant	Averaging Period	WHO Guideline Value (µg/m³) (i)	South Africa NAAQS (µg/m³)
Sulfur Dioxide (SO_2)	1-year 24-hour 1-hour 10-minute	- 125 (IT1) 50 (IT2) (a) 40 (AQ level) - -	50 125 (b) 350 (c) 500 (d)
Nitrogen Dioxide (NO_2)	1-year 24-hour 1-hour	40 (IT1) 30 (IT2) 20 (IT3) 10 (AQ level) 120 (IT1) 50 (IT2) 25 (AQ level)	40 200 (c)
Particulate Matter (PM_{10})	1-year 24-hour	70 (IT1) 50 (IT2) 30 (IT3) 20 (IT4) 15(AQ level) 150 (IT1) 100 (IT2) 75 (IT3) 50 (IT4) 45 (AQ level)	40 (e) (b) 75 (e)
Particulate Matter ($PM_{2.5}$)	1-year 24-hour	35 (IT1) 25 (IT2) 15 (IT3) 10 (IT4) 5 (AQ level) 75 (IT1) 50 (IT2) 37.5 (IT3) 25 (IT4) 15 (AQ level)	25 (f) 20 (g) 15 (h) 65 (f) 40 (g) 25 (h)

Notes:

(a) Intermediate goal based on controlling motor vehicle emissions; industrial emissions and/or emissions from power production. This would be a reasonable and feasible goal to be achieved within a few years for some developing countries and lead to significant health improvement.
(b) 4 permissible frequencies of exceedance per year
(c) 88 permissible frequencies of exceedance per year
(d) 526 permissible frequencies of exceedance per year
(e) Applicable from 1 January 2015.
(f) Applicable immediately to 31 December 2015.
(g) Applicable 1 January 2016 to 31 December 2029.
(h) Applicable 1 January 2030.
(i) WHO (2021) for 24-hour averages 99th percentile (i.e., 3-4 exceedance days per year).

2.2.3 Dustfall Limits

Air quality standards are not defined by all countries for dust deposition, although some countries may make reference to annual average dust fall thresholds above which a 'loss of amenity' may occur. In the southern African context, widespread dust deposition impacts occur as a result of windblown dust from mine tailings and natural sources, from mining operations and other fugitive dust sources.

South Africa has published the National Dust Control Regulations (NDCR) on the 1st of November 2013 (Government Gazette No. 36974). The purpose of the regulations is to prescribe general measures for the control of dust in all areas including residential and light commercial areas. Similarly, Botswana published dust deposition evaluation criteria (BOS 498:2013). According to these limits, an enterprise may submit a request to the authorities to operate within the Band 3 (action band) for a limited period, providing that this is essential in terms of the practical operation of the enterprise (for example the final removal of a tailings deposit) and provided that the best available control technology is applied for the duration. No margin of tolerance will be granted for operations that result in dustfall rates in the Band 4 (alert band). This four-band scale is presented in Table 2-2.

Table 2-2: Bands of dustfall rates

Band Number	Band Description	30 Day Average Dustfall Rate (mg/m^2-day)	Comment
1	Residential	Dustfall rate < 600	Permissible for residential and light commercial
2	Industrial	600 < Dustfall rate < 1 200	Permissible for heavy commercial and industrial
3	Action	1 200 < Dustfall rate < 2 400	Requires investigation and remediation if two sequential months lie in this band, or more than three occur in a year.
4	Alert	2 400 < Dustfall rate	Immediate action and remediation required following the first exceedance. Incident report to be submitted to relevant authority.

2.3 International Conventions

The technical reference documents published in the IFC Environmental, Health and Safety (EHS) Guidelines provide general and industry specific examples of Good International Industry Practice (GIIP). The General EHS Guidelines are designed to be used together with the relevant Industry Sector EHS Guidelines (IFC, 2007).

The IFC EHS Guidelines provide a general approach to air quality management for a facility, including the following:

- Identifying possible risks and hazards associated with the project as early on as possible and understanding the magnitude of the risks, based on:
  - the nature of the project activities; and,
  - the potential consequences to workers, communities, or the environment if these hazards are not adequately managed or controlled.
- Preparing project- or activity-specific plans and procedures incorporating technical recommendations relevant to the project or facility;
- Prioritising the risk management strategies with the objective of achieving an overall reduction of risk to human health and the environment, focusing on the prevention of irreversible and / or significant impacts;
- When impact avoidance is not feasible, implementing engineering and management controls to reduce or minimise the possibility and magnitude of undesired consequence; and,
- Continuously improving performance through a combination of ongoing monitoring of facility performance and effective accountability.

Significant impacts to air quality should be prevented or minimised by ensuring that:

- Emissions to air do not result in pollutant concentrations exceeding the relevant ambient air quality guidelines or standards. These guidelines or standards can be national guidelines or standards or in their absence WHO AQGs or any other international recognised sources.
- Emissions do not contribute significantly to the relevant ambient air quality guidelines or standards. It is recommended that 25% of the applicable air quality standards are allowed to enable future development in a given airshed. Thus, any new development should not result in ground level concentrations exceeding 25% of the guideline value.
- The EHS recognises the use of dispersion models to assess potential ground level concentrations. The models used should be internationally recognised or comparable.

2.3.1 Degraded Airsheds or Ecological Sensitive Areas

The IFC provides further guidance on projects located in degraded airsheds (IFC, 2007), i.e., areas where the national/ WHO/ other recognised international Air Quality Guidelines are significantly exceeded or where the project is located next to areas regarded as ecological sensitive such as national parks. The project is not located in an ecologically sensitive area, and the airshed is not regarded to be degraded.

2.3.2 Fugitive Source Emissions

According to the IFC (IFC, 2007), fugitive source emissions refer to emissions that are distributed spatially over a wide area and confined to a specific discharge point. These sources have the potential to result in more significant ground level impacts per unit release than point sources. It is therefore necessary to assess this through ambient quality assessment and monitoring practices.

2.4 Recommended Guidelines and Objectives

The IFC references the WHO guidelines but indicates that any other internationally recognized criteria can be used such as the United States (US) Environmental Protection agency (EPA) or the EC. It was, however, found that merely adopting the WHO guidelines would result in exceedances of these guidelines in many areas due to the arid environment in the country, and specifically in Namibia. The WHO states that these AQG and interim targets should be used to guide standard-setting processes and should aim to achieve the lowest concentrations possible in the context of local constraints, capabilities, and public health priorities. These guidelines are also aimed at urban environments within developed countries (WHO, 2005). For this reason, the South African NAAQS are also referenced since these were developed after a thorough review of all international criteria and selected based on the socio, economic and ecological conditions of the country.

In the absence of guidelines on ambient air concentrations for Namibia, reference is made to the AQO. These objectives are based on the WHO interim targets and SA NAAQS (Table 2-1). The criteria were selected on the following basis:

- The WHO IT3 was selected for particulates since these limits are in line with the SA NAAQSs, and the latter are regarded feasible limits for the arid environment of Namibia.
- Even though $PM_{2.5}$ emissions are mainly associated with combustion sources and mainly a concern in urban environments, it is regarded good practice to include as health screening criteria given the acute adverse health effects associated with this fine fraction. Also, studies found that desert dust with an aerodynamic diameter 2.5 µm cause premature mortality.

- For SO_2, there is no IT3, and the IT2 was selected since the WHO states: "This would be a reasonable and feasible goal for some developing countries (it could be achieved within a few years) which would lead to significant health improvements that, in turn, would justify further improvements (such as aiming for the AQG value)".
- The WHO provides no interim targets for NOx. The AQGs are in line with the SA NAAQSs and therefore regarded as achievable limits.
- The Botswana and South African criteria for dust fallout are the same and with limited international criteria for dust fallout, these were regarded applicable.

The proposed Air Quality Objectives (AQOs) as set out in Table 2-3 are intended to be used as indicators during the impact assessment.

Table 2-3: Proposed Air Quality Objectives for the project

Pollutant	Averaging Period	Criteria	Reference
NO_2	1-hour average (µg/m³)	200[(a)]	WHO AQG & EC & SA NAAQS
	Annual average (µg/m³)	40	WHO AQG & EC & SA NAAQS
SO_2	1-hour average (µg/m³)	350[(a)]	EC Limit & SA NAAQS (no WHO guideline)
	24-hour average (µg/m³)	50[(b)]	WHO IT2 (seen as a per 40% of the SA and EC limits)
	Annual average (µg/m³)	50	SA NAAQS (no WHO guideline)
Particulate matter (PM_{10})	24-hour average (µg/m³)	75[(b)]	WHO IT3 & SA NAAQS (as per SEMP AQMP)
	Annual average (µg/m³)	40	SA NAAQS (as per SEMP AQMP)
Particulate matter ($PM_{2.5}$)	24-hour average (µg/m³)	37.5[(b)]	WHO IT (as per SEMP AQMP)
	Annual average (µg/m³)	15	WHO IT3 & SA NAAQS (as per SEMP AQMP)
Dustfall	30-day average (mg/m²/day)	600[(c)]	SA NDCR & Botswana residential limit
		1 200[(c)]	SA NDCR & Botswana industrial limit
		2 400	Botswana Alert Threshold

Notes: [(a)] Not to be exceeded more than 88 hours per year (SA)

[(b)] Not to be exceeded more than 4 times per year (SA)

[(c)] Not to be exceeded more than 3 times per year or 2 consecutive months

3 DESCRIPTION OF THE BASELINE ENVIRONMENT

3.1 Site Description and Sensitive Receptors

The closest communities include Hochfeld and Seeis, both of which are located more than 30 km from the project area. Potential AQSRs within the study area include a farmstead ~2.5 km to the east and ~3.5 km to the south of the mine boundary (Figure 3-1).

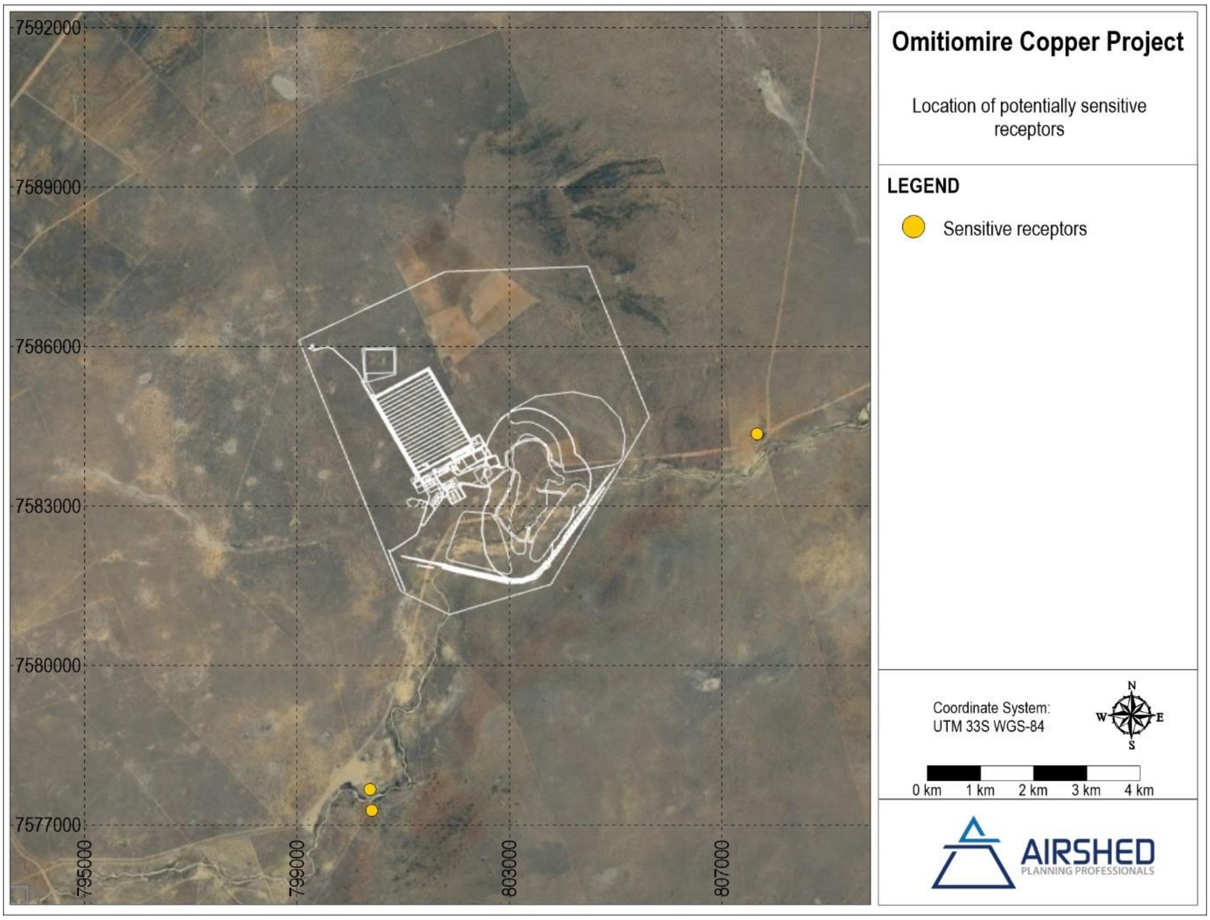

Figure 3-1: Identified AQSRs within the study area

3.2 Atmospheric Dispersion Potential

Meteorological mechanisms govern the dispersion, transformation and eventual removal of pollutants from the atmosphere. The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. Dispersion comprises vertical and horizontal components of motion. The stability of the atmosphere and the depth of the surface-mixing layer define the vertical component. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume 'stretching'. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. Pollution concentration levels therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field.

A description of the wind field, temperature, precipitation, and atmospheric stability is provided in the following section. Modelled Weather Research and Forecasting (WRF)[3] meteorological data for the period 2020 to 2022 was utilised which include wind speed (km/hr), wind direction (degrees), temperature (°C), humidity (%), barometric pressure (Pa) and rainfall (mm).

3.2.1 Surface Wind Field

The wind direction, and the variability in wind direction, determines the general path that air pollutants will follow, and the extent of crosswind spreading. Wind roses comprise 16 spokes, which represent the directions from which winds blew during the period. The colours used in the wind roses below, reflect the different categories of wind speeds; the red area, for example, representing winds higher than 6 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. The frequency with which calms occurred refers to periods during which the wind speed was below 1 m/s.

Period, daytime and night-time wind roses for the study area, based on the modelled WRF meteorological data for three-year period: 1 January 2020 to 31 December 2022 are depicted in Figure 3-2.

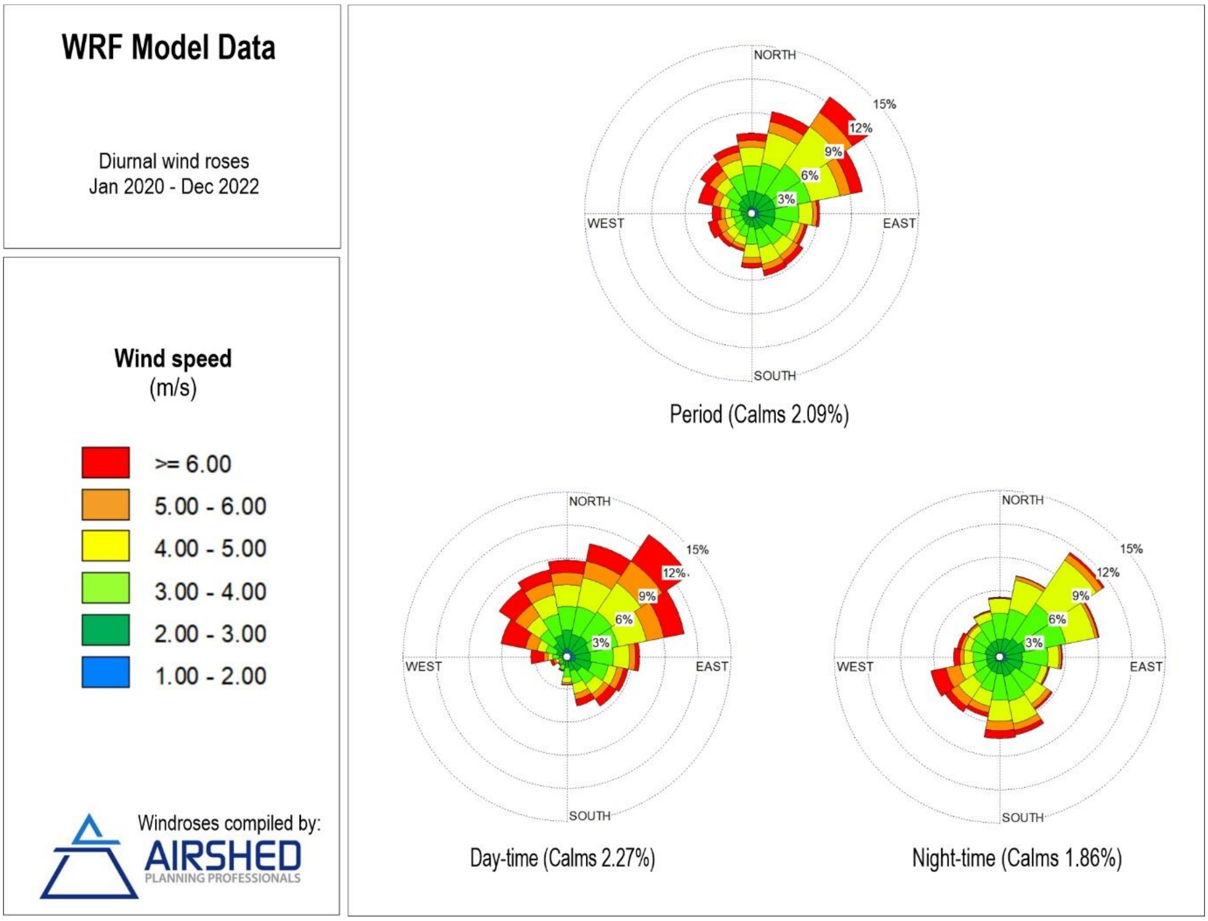

Figure 3-2: Period, day- and night-time wind roses based on modelled WRF data (1 January 2020 to 31 December 2022)

[3] The Weather Research and Forecasting (WRF) Model is a state-of-the-art mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting applications. It features two dynamical cores, a data assimilation system, and a software architecture supporting parallel computation and system extensibility.

The predominant wind direction for the study area is from the northeast which is evident in the day- and night-time wind roses as well. Calm conditions (i.e., wind speeds of less than 1 m/s) occurred for 2.09% of the period.

3.2.2 Temperature

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the emission plume and the ambient air, the higher the plume is able to rise), and determining the development of the mixing and inversion layers.

Monthly mean, maximum and minimum temperatures are given in Table 3-1. Diurnal temperature variability is presented in Figure 3-3. Average monthly temperatures ranged between 11°C and 23.8°C. During the day, temperatures increase to reach maximum at about 16:00 in the late afternoon. Ambient air temperature decreases to reach a minimum at between 06:00 and 07:00.

Table 3-1: Monthly temperature summary (WRF data, 2018 to 2020)

Monthly Minimum, Maximum and Average Temperatures (°C)												
Parameter	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Minimum	16.2	15.4	13.3	10.5	5.2	1.8	1.8	3.7	8.6	12.6	14.5	15.0
Average	23.2	22.3	20.7	18.8	14.4	10.6	11.0	14.2	19.1	21.9	23.7	23.8
Maximum	29.3	28.2	27.1	26.2	23.7	20.5	21.1	24.7	29.0	30.4	30.9	30.9

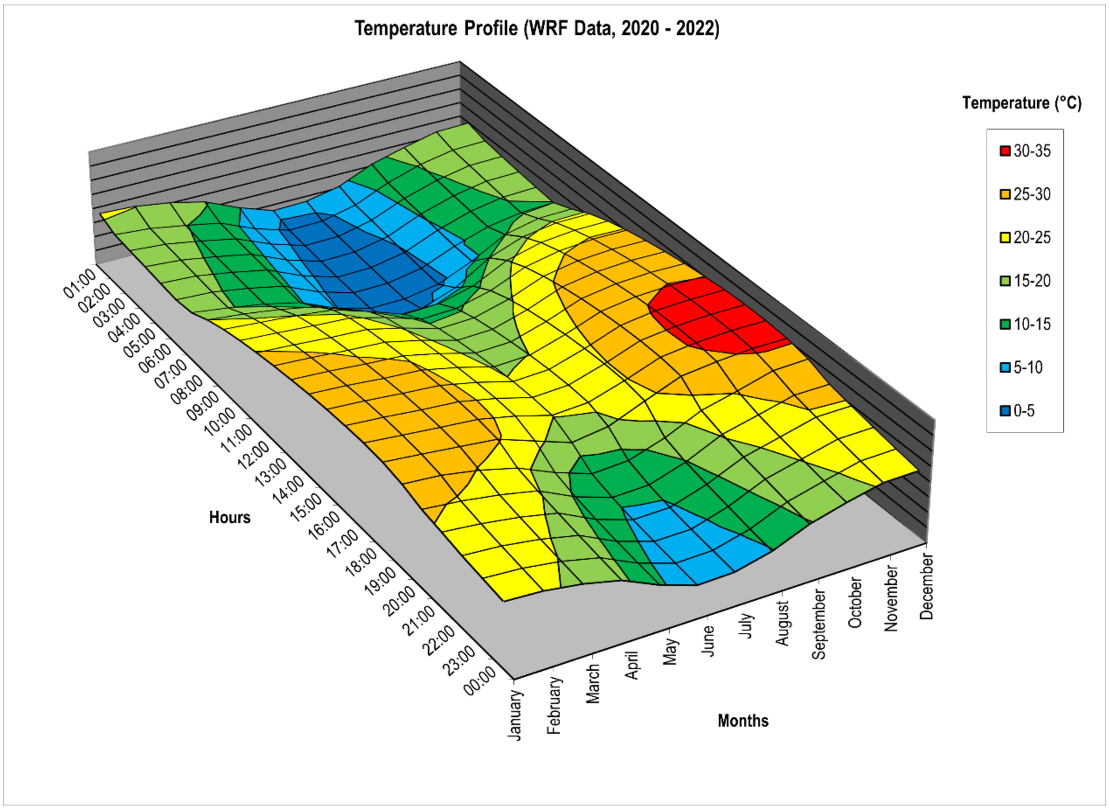

Figure 3-3: Diurnal temperature profile (WRF data, 2018 to 2020)

3.2.3 Atmospheric Stability

The new generation air dispersion models differ from the models traditionally used in a number of aspects, the most important of which are the description of atmospheric stability as a continuum rather than discrete classes. The atmospheric boundary layer properties are therefore described by two parameters: the boundary layer depth and the Monin-Obukhov length, rather than in terms of the single parameter Pasquill Class. The Monin-Obukhov length (LMo) provides a measure of the importance of buoyancy generated by the heating of the ground and mechanical mixing generated by the frictional effect of the earth's surface. Physically, it can be thought of as representing the depth of the boundary layer within which mechanical mixing is the dominant form of turbulence generation (CERC, 2004). The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. During the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface. Night times are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds and less dilution potential. During windy and/or cloudy conditions, the atmosphere is normally neutral. For low level releases, the highest ground level concentrations would occur during weak wind speeds and stable (night-time) atmospheric conditions. The atmospheric stability for the site is provided in Figure 3-4.

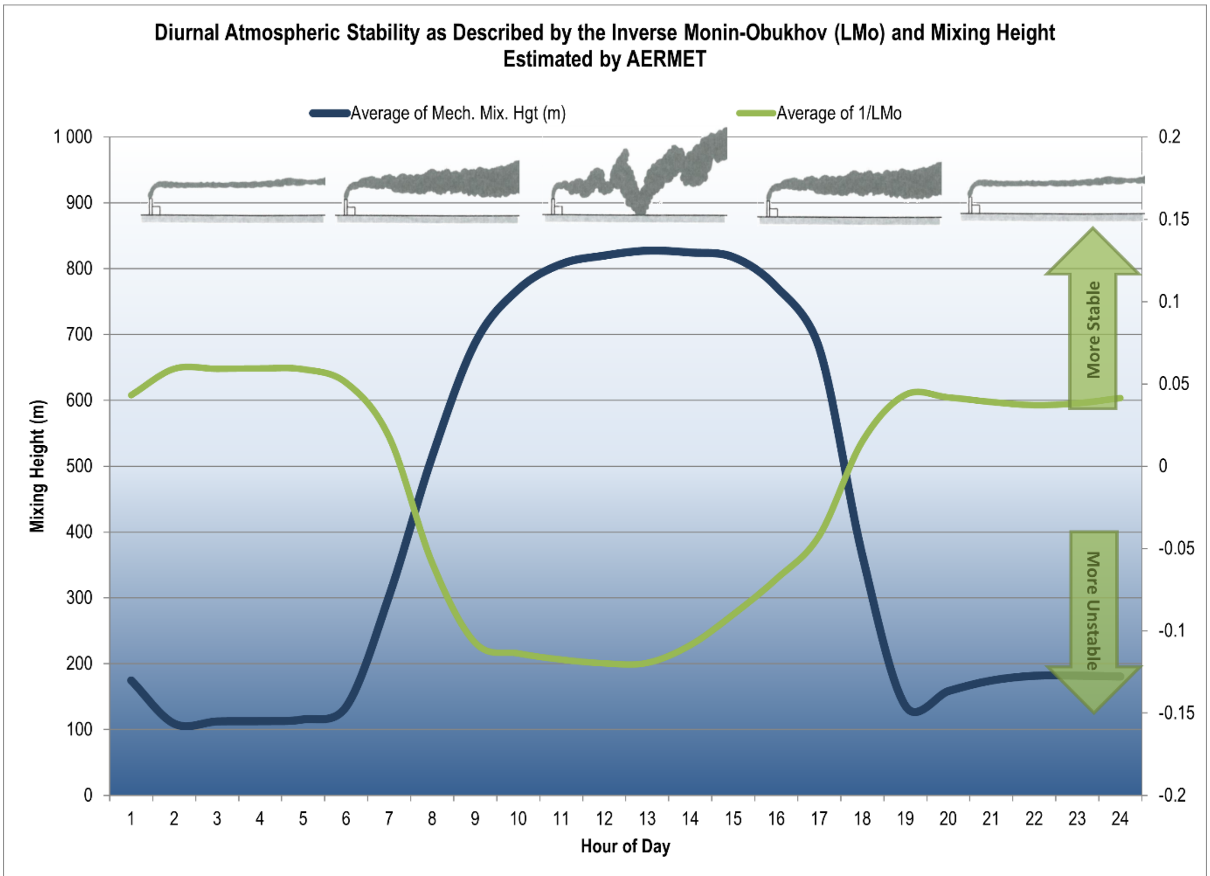

Figure 3-4: The diurnal atmospheric stability for the site as estimated with AERMET

3.3 Current Ambient Air Quality

The project site has a dust fallout monitoring network, comprising of 11 single dust fallout buckets (Figure 3-5). Measured dust deposition rates were obtained from the dust monitoring campaign undertaken for Craton for the period July 2022 to September 2023.

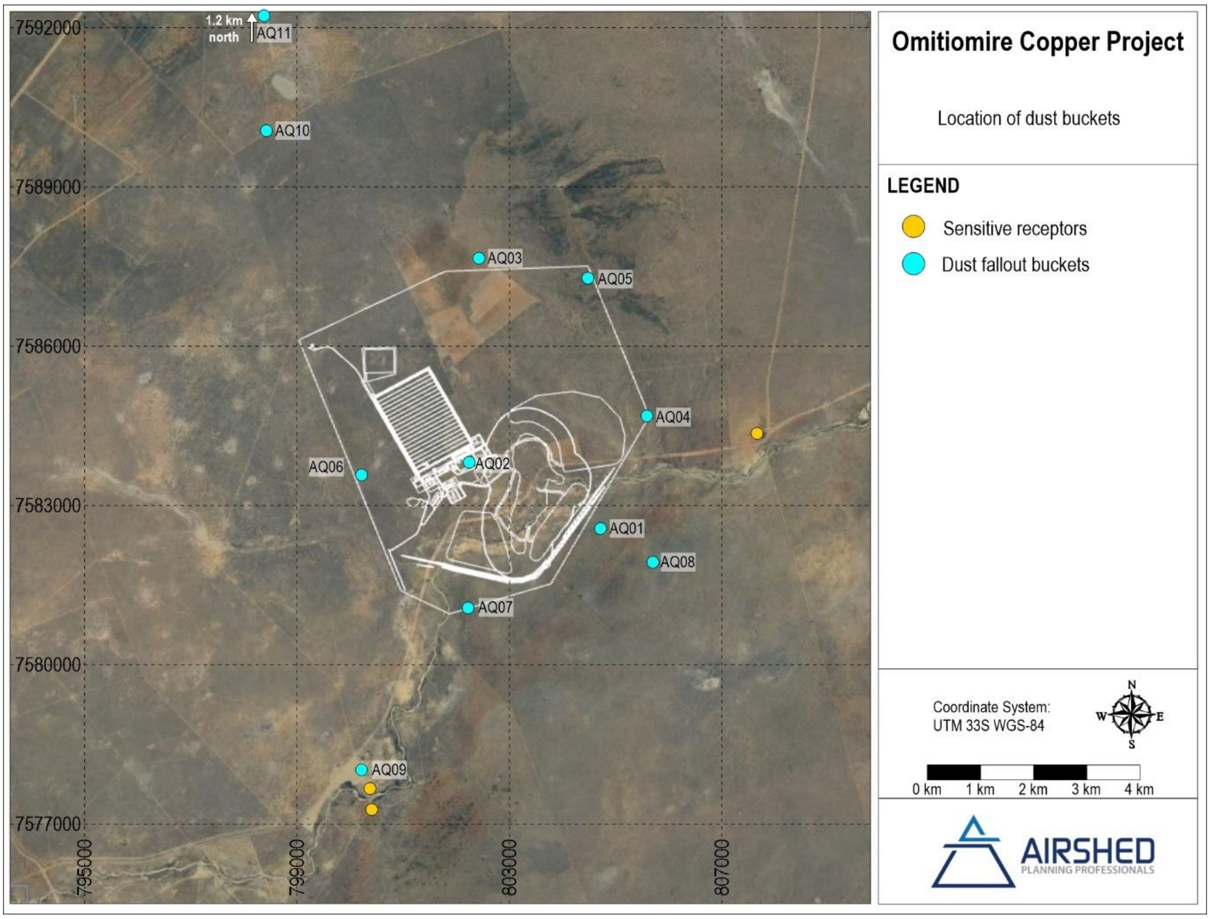

Figure 3-5: Location of current dust fallout network at the project site

The measured dust fallout for the period July 2022 to September 2023 is provided in Table 3-2 and illustrated in Figure 3-6. Dustfall rates were low on average (70 mg/m²/day) across all sites over the study area, and well below the residential (600 mg/m²/day) and industrial (1 200 mg/m²/day) AQOs (Table 2-3) over the 16 months.

Table 3-2: Measured dust fallout for the project site for the period July 2022 to September 2023

Date	Measured dust fallout (mg/m²/day)										
	AQ01	AQ02	AQ03	AQ04	AQ05	AQ06	AQ07	AQ08	AQ09	AQ10	AQ11
Jun-22	92	95	136	99	98	95	100				
Jul-22	119	52	67	54	51	64	45				
Aug-22	19	86	19	19	17	22	42	19	19		
Sep-22	124	126	123	128	122	126	126	125	147		
Oct-22	127	128	207	124	106	126	125	113			
Nov-22	138	129	128	360	123	104	114	129	101		
Dec-22	13	56	80		31	37	41	19	38		
Jan-23	14	39	332	168	25	33	13	12	21		
Feb-23	27	48	30	90	34	36	72		32		
Mar-23	34	26	250	46	26	248	38	30	42		
Apr-23	34	45	115	30	41	260	26	35	53		
May-23	15	18	13	24	26	31	39	42	54		
Jun-23	36	39	23	38	38	22	35	19	26	16	
Jul-23	72	77	84	81	76	81	77	77	131	111	109
Aug-23	38	34	34	33	24	29	38	43	67	41	63
Sep-23	38	29	34	36	27	30	30	32	60	36	56

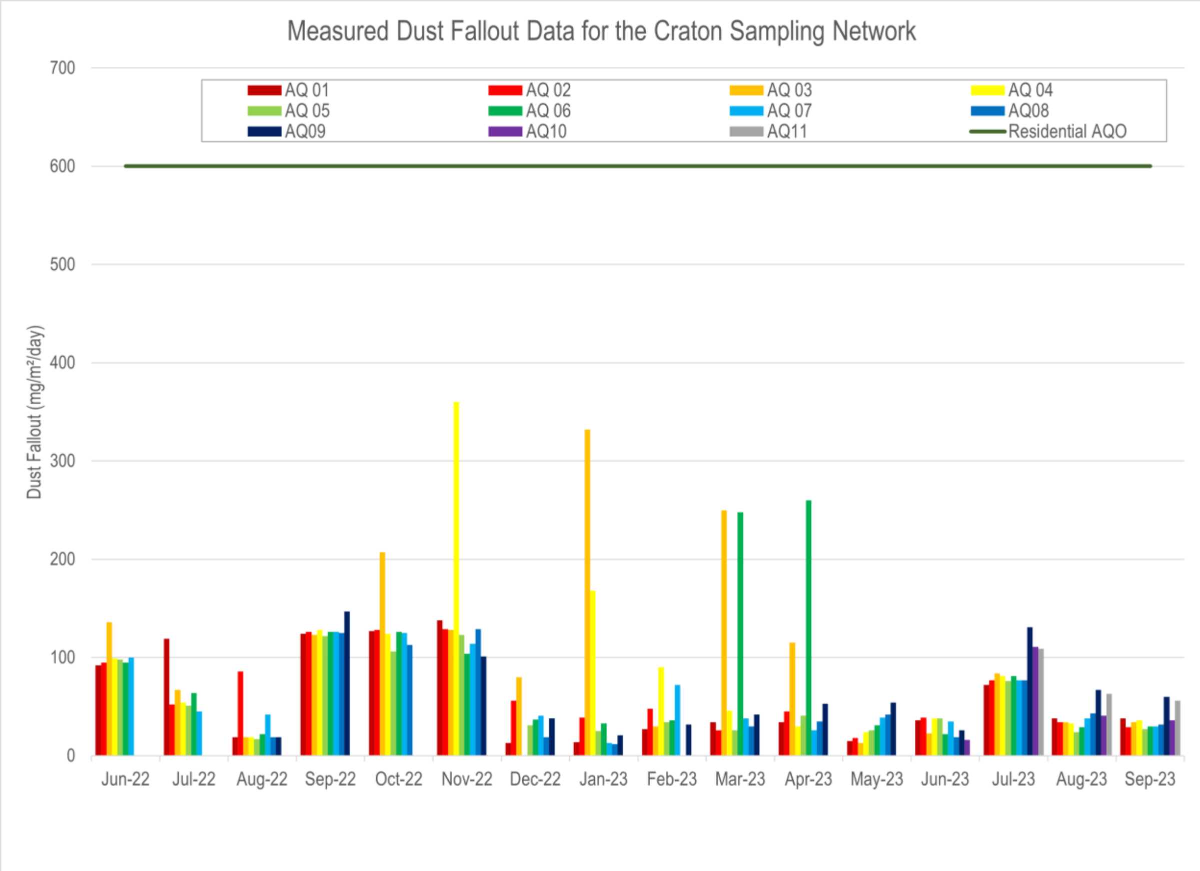

Figure 3-6: Measured dust fallout for the project site for the period July 2022 to September 2023

3.4 Existing Air Quality within the Khomas Region

The identification of existing sources of emissions in the Khomas Region and the characterisation of existing ambient pollutant concentrations is fundamental to the assessment of the potential for cumulative impacts and synergistic effects given the proposed mining operations and their associated emissions.

The Khomas Region is located in the central part of Namibia and is bounded by the escarpment to the west and to the east the Namibian savannah region of Omaheke. To the south, the Khomas Region is bordered by the Hardap region of Namibia, which extends west to east from the Atlantic Ocean to the neighbouring countries of Botswana and South Africa.

The region falls just outside the west coast arid zone of Southern Africa and is characterised by low to medium rainfall with extreme temperature ranges and unique climatic factors influencing the natural environment and biodiversity. Extremely cold temperatures associated with southerly winds are a common phenomenon during the winter months and is derived primarily from natural sources. These sources are intermittent sources, giving rise to dust emissions only under conditions of high wind speeds. Anthropogenic sources such as unpaved roads and agricultural activities continuously add to the atmospheric dust load in the Khomas Region.

Sources identified as possibly impacting on air quality in the region include, but are not limited to:

- Fugitive emissions from mining operations;
- Vehicle tailpipe emissions from national and main roads;
- Windblown dust from natural mineral sources; and

- Various miscellaneous fugitive dust sources (agricultural activities, wind erosion of open areas, vehicle-entrainment of dust along paved and unpaved roads).

3.4.1 Vehicle Tailpipe Emissions

Air pollution from vehicle emissions may be grouped into primary and secondary pollutants. Primary pollutants are those emitted directly into the atmosphere, and secondary, those pollutants formed in the atmosphere as a result of chemical reactions, such as hydrolysis, oxidation, or photochemical reactions. The significant primary pollutants emitted by vehicles include CO_2, CO, hydrocarbons (HCs), SO_2, NO_x, particulates and lead. Secondary pollutants include: nitrogen dioxide (NO_2), photochemical oxidants (e.g., ozone), HCs, sulphur acid, sulphates, nitric acid, nitric acid and nitrate aerosols. Toxic hydrocarbons emitted include benzene, 1.2-butadiene, aldehydes and polycyclic aromatic hydrocarbons (PAH). Benzene represents an aromatic HC present in petrol, with 85% to 90% of benzene emissions emanating from the exhaust and the remainder from evaporative losses.

Vehicle tailpipe emissions are also localised sources and unlikely to impact far-field. A network of roads exists close to the project site, and these include the unpaved M53, of which a section will be used as hauling ore from open pit to the processing plant at the project operations. This road is primarily utilised by tourists and farmers in the area. Other public roads located to the proposed site include those located on the surrounding farmlands.

3.4.2 Mining Operations in the Region

Fugitive dust sources associated with mining activities include drilling and blasting operations, materials handling activities, vehicle-entrainment by haul vehicles and wind-blown dust from stockpiles. Mining operations represent potentially the most significant sources of fugitive dust emissions ($PM_{2.5}$, PM_{10} and TSP) with small amounts of NO_x, CO, SO_2, methane, and CO_2 being released during blasting operations and from mine trucks.

Experience has shown that fugitive dust emissions due to on-site operations are typically only of concern within 3 km of the mine boundary, depending on the location of the mine boundary and extent of the mining operations. This is the reason for the current manner in which atmospheric emissions are treated for mining operations. Dust suppression methods that are most frequently used in local mining operations include wet suppression and chemical stabilisation of haul roads and storage piles, and the vegetation or rock cladding of tailings impoundments.

There are no current mining operations within the study region that will add cumulative effects to the assessment of the proposed project.

3.4.3 Fugitive Dust Sources

Fugitive dust emissions may occur as a result of vehicle entrained dust from local paved and unpaved roads, and wind erosion from open areas. The extent of particulate emissions from the main roads will depend on the number of vehicles using the roads and the silt loading on the roadways. The extent, nature and duration of agricultural activities and the moisture and silt content of soils are required to be known in order to quantify fugitive emissions from this source. The quantity of wind-blown dust is similarly a function of the wind speed, the extent of exposed areas and the moisture and silt content of such areas.

3.5 Identification of Possible Sensitive Receptors in the Area

The evaluation criteria are based on human exposure to specific criteria pollutants and as such, possible AQSRs were identified where the public is likely to be unwittingly exposed. The residential areas within the study area are provided in Section 3.1. Potential impacts from the proposed project will be assessed, taking into consideration the location of the AQSRs in the study area.

4 IMPACT ASSESSMENT

The emissions inventory, dispersion modelling and results are discussed in Section 4.1, 4.2 and Section 4.3 respectively.

4.1 Atmospheric Emissions

4.1.1 Construction Phase

Construction normally comprises a series of different operations including land clearing, topsoil removal, material loading and hauling, stockpiling, grading, bulldozing, compaction, etc. Most of the infrastructure such as surface haul roads and stockpiles required for the Life-of-Mine (LOM) will be constructed during the first year of the project. Waste rock dumps (WRDs) will progress over time with haul trucks tipping the waste on the top elevation of the dumps with the dozers pushing the waste material down. These actions will cause the WRDs to progress horizontally over time. Ore stockpiles will be constructed in close vicinity to the primary crusher tipping point to minimise the reclamation costs.

The main pollutant of concern from construction operations is PM, including PM_{10}, $PM_{2.5}$ and TSP. PM_{10} and $PM_{2.5}$ concentrations are associated with potential health impacts due to the size of the particulates being small enough to be inhaled. Nuisance effects are caused by the TSP fraction (20 µm to 75 µm in diameter) resulting in soiling of materials and visibility reductions. This could in effect also have financial implications due to the requirement for more cleaning materials.

All operations associated with the construction phase are listed in Table 1-1. Each of the operations has their own duration and potential for dust generation. It is therefore often necessary to estimate area wide construction emissions, without regard to the actual plans of any individual construction process. Quantified construction emissions are usually lower than operational phase emissions and due to their temporary nature and duration, and the likelihood that these activities will not occur concurrently at all portions of the site; dispersion simulation was not undertaken for construction emissions.

The US EPA documents emission factors which aim to provide a general rule-of-thumb as to the magnitude of emissions which may be anticipated from construction operations (US EPA, 2006). The quantity of dust emissions is assumed to be proportional to the area of land being worked and the level of construction activity. The approximate emission factors for general construction activity operations are given as:

$$\mathbf{E = 2.69\ Mg/hectare/month\ of\ activity\ (269\ g/m^2/month)}$$

The PM_{10} fraction is given as ~39% of the US EPA total suspended particulate factor. The $PM_{2.5}$ fraction was assumed to be 50% of the PM_{10} fraction. These emission factors are most applicable to construction operations with (i) medium activity levels, (ii) moderate silt contents, and (iii) semiarid climates. The emission factor for TSP considers 42 hours of work per week of construction activity. Test data were not sufficient to derive the specific dependence of dust emissions on correction parameters, and because the above emission factor is referenced to TSP, use of this factor to estimate PM_{10} emissions will result in conservatively high estimates. Also, because derivation of the factor assumes that construction activity occurs 30 days per month, the above estimate is somewhat conservatively high for TSP as well.

Areas assumed to be cleared of vegetation for infrastructure development and mining preparation are listed in Table 4-1. Assuming all areas to be developed simultaneously within the period of a year, the resulting emission estimates are 1 340 tpa for TSP, 523 tpa for PM_{10} and 262 tpa for $PM_{2.5}$.

Table 4-1: Construction areas

Mining Area	Area (m²)
WRDs	3 050 400
Processing plant area and heap leach pad	1 808 000
Ore storage area	124 000
Total	**4 982 400**

4.1.2 Operational Phase

Quantification of emissions from the proposed project are restricted to fugitive releases (non-point releases). Particulates are the main pollutant of concern from mining operations. Gaseous emissions (i.e., SO_2, NO_x, CO and VOCs) will primarily result from diesel combustion, both from mobile and stationary sources. Gaseous emissions were not quantified as information on expected diesel consumption was not available at the time of the study. The impacts from exhaust gas emissions are also expected to be localised.

The maximum ore and waste rock throughput for the project was provided as 6.5 million tons per annum (Mtpa) and 41.8 Mtpa respectively.

Wind erosion can occur from the WRDs, ore stockpiles and the heap leach pad. Wind erosion is a complex process, including three different phases of particle entrainment, transport, and deposition. It is primarily influenced by atmospheric conditions (e.g., wind, precipitation and temperature), soil properties (e.g., soil texture, composition and aggregation), land-surface characteristics (e.g., topography, moisture, aerodynamic roughness length, vegetation and non-erodible elements) and land-use practice (e.g., farming, grazing and mining). For wind erosion to occur, the wind speed needs to exceed a certain threshold, called the threshold velocity. This relates to gravity and the inter-particle cohesion that cause the individual particles to resist removal. Thus, for particles to become airborne, the wind shear at the surface must exceed the gravitational and cohesive forces acting upon them, called the threshold friction velocity (Shao, 2008).

The emission equations used to quantify emissions from the proposed activities are shown in Table 4-2. Both unmitigated and mitigated activities were assessed. The estimated control efficiencies as obtained from literature (NPI, 2012) for the various project activities are given in Table 4-4.

A summary of estimated particulate emissions from the proposed project operations is provided in Table 4-5.

Table 4-2: Emission factors used to qualify the routine emissions from the operational phase for the proposed project

Activity	Emission Equation	Source	Information assumed/provided
Vehicle entrainment on unpaved surfaces	$E = k(s/12)^a (W/3)^b$ Where, E = size-specific emission factor (lb/VKT) s = surface material silt content (%) W = mean vehicle weight (tons) The particle size multiplier (k) is given as 0.15 for $PM_{2.5}$, 1.5 for PM_{10}, and as 4.9 for TSP. A is given as 0.9 for $PM_{2.5}$ and PM_{10} and 0.7 for TSP. A is given as 0.45 for $PM_{2.5}$, PM_{10} and TSP.	US-EPA AP42 Section 13.2.2	Unpaved road for transport of waste to WRDs and ore to ore storage pile area. In the absence of site-specific silt data, use was made of US EPA default mean silt loading of 8.3% for the unpaved haul road and access road. The haul trucks to be used were given as Komatsu HD785 (92 t capacity trucks). The truck capacity for product trucks was provided as 30 t. Maximum ore and waste throughputs were assumed for the assessment. *75% and 90% control efficiency (CE) were assumed for the mitigated scenarios.*
Blasting	$E_{TSP} = 0.00022\ x\ A^{1.5}$ Where, A = area blasted in m² PM_{10} is given as 52% of TSP emissions and $PM_{2.5}$ is assumed to be 3% of TSP emissions	NPI Section: Mining	Average blast area per month was provided as 25 000 m² and that there would be 2 blasts per week.
Drilling	$E_{TSP} = 0.59\ kg\ of\ dust\ /drill\ hole$ PM_{10} is given as 52% of TSP emissions and $PM_{2.5}$ is assumed to be 3% of TSP emissions	NPI Section: Mining	It was provided that the mine would drill 100 holes per day. *99% CE were assumed for the mitigated scenarios.*
Excavators/ shovels/ front-end loaders	$E_{TSP} = 0.025\ kg/t\ material\ moved$ $E_{PM10} = 0.012\ kg/t\ material\ moved$ Fraction of $PM_{2.5}$ taken from US-EPA materials handling emission factor ratio for TSP to $PM_{2.5}$	NPI Section: Mining	Maximum ore and waste throughputs were assumed for the assessment.
Trucks (dumping)	$E_{TSP} = 0.012\ kg/t\ material\ moved$ $E_{PM10} = 0.0043\ kg/t\ material\ moved$ Fraction of $PM_{2.5}$ taken from US-EPA materials handling emission factor ratio for TSP to $PM_{2.5}$	NPI Section: Mining	Maximum ore and waste throughputs were assumed for the assessment.

Activity	Emission Equation	Source	Information assumed/provided
Loading stockpiles	$E_{TSP} = 0.004\ kg/t\ material\ moved$ $E_{PM10} = 0.0017\ kg/t\ material\ moved$ Fraction of $PM_{2.5}$ taken from US-EPA materials handling emission factor ratio for TSP to $PM_{2.5}$	NPI Section: Mining	Maximum ore and waste throughputs were assumed for the assessment.
Unloading from stockpiles	$E_{TSP} = 0.03\ kg/t\ material\ moved$ $E_{PM10} = 0.013\ kg/t\ material\ moved$ Fraction of $PM_{2.5}$ taken from US-EPA materials handling emission factor ratio for TSP to $PM_{2.5}$	NPI Section: Mining	Maximum ore and waste throughputs were assumed for the assessment.
Miscellaneous transfer points (including conveying)	$E_{TSP} = 0.00032\ kg/t\ material\ moved$ $E_{PM10} = 0.00015\ kg/t\ material\ moved$ Fraction of $PM_{2.5}$ taken from US-EPA materials handling emission factor ratio for TSP to $PM_{2.5}$	NPI Section: Mining	Maximum ore and waste throughputs were assumed for the assessment.
Crushing and screening	Primary (for high moisture ore (>4%)): $E_{TSP} = 0.01\ kg/t\ material\ processed$ $E_{PM10} = 0.004\ kg/t\ material\ processed$ $E_{PM2.5} = 0.00074\ kg/t\ material\ processed$ Secondary (for high moisture ore (>4%)): $E_{TSP} = 0.03\ kg/t\ material\ processed$ $E_{PM10} = 0.012\ kg/t\ material\ processed$ $E_{PM2.5} = 0.00222\ kg/t\ material\ processed$ Tertiary (for high moisture ore (>4%)): $E_{TSP} = 0.03\ kg/t\ material\ processed$ $E_{PM10} = 0.01\ kg/t\ material\ processed$ $E_{PM2.5} = 0.00185\ kg/t\ material\ processed$ Fraction of $PM_{2.5}$ taken from US-EPA crushed stone emission factor ratio for tertiary crushing	NPI Section: Mining	Primary, secondary and tertiary is present for the project. Maximum ore throughputs were assumed for the assessment. *50% efficiency was assumed for the crushing mitigated scenario.*

Activity	Emission Equation	Source	Information assumed/provided
Wind Erosion	$E(i) = G(i)10^{(0.134(\%clay)-6)}$ For $G(i) = 0.261\left[\frac{P_a}{g}\right]u^{*3}(1+R)(1-R^2)$ And $R = \frac{u_*^{\ t}}{u^*}$ where, $E_{(i)}$ = emission rate (g/m²/s) for particle size class i P_a = air density (g/cm³) G = gravitational acceleration (cm/s³) u_*^t = threshold friction velocity (m/s) for particle size i u^* = friction velocity (m/s)	Marticorena & Bergametti, 1995	Particle size distribution used for the assessment is provided in Table 4-3. Hourly emission rate file was calculated and simulated.

Table 4-3: Particle size distribution for the run-of-mine (ROM) and waste rock material

Waste rock material		ROM	
Particle size (µm)	**Particle size fraction**	**Particle size (µm)**	**Particle size fraction**
878.67	0.000	2000	0.320
754.23	0.010	1180	0.218
647.41	0.038	850	0.080
555.71	0.047	600	0.071
477.01	0.044	300	0.118
409.45	0.047	150	0.094
351.46	0.048	75	0.048
301.68	0.049	38	0.019
258.95	0.035	25	0.011
222.28	0.043	10	0.004
190.8	0.041	5	0.005
163.77	0.046	2	0.007
140.58	0.053	1	0.006
120.67	0.055		
103.58	0.035		
88.91	0.031		
76.32	0.033		
65.51	0.038		
56.23	0.039		
48.27	0.036		
41.43	0.030		
35.56	0.026		
30.53	0.024		
26.2	0.022		
22.49	0.020		
19.31	0.017		
16.57	0.014		
14.22	0.012		
12.21	0.010		
10.48	0.009		
9	0.008		
7.72	0.007		
6.63	0.007		
5.69	0.006		
4.88	0.005		
4.19	0.004		
3.6	0.005		
2.5	0.002		

Table 4-4: Estimated control efficiencies provided for mitigation measures applied to various project operations (NPI, 2012)

Operation/Activity	Control method and emission reduction
Unpaved surface haul roads	75% CE for water sprays with chemical suppressants
Unpaved surface haul roads	90% CE for chemical suppressants
Drilling	99% CE for fabric filters
Crushing and screening	50% CE for water sprays keeping ore wet

Table 4-5: Calculated particulate emission rates from unmitigated and mitigated routine project operations

ACTIVITY	Emissions (tpa)			% Contribution			Rank
	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	TSP
Unmitigated							
Vehicle entrainment	20 568.51	5 848.94	584.89	89.18	84.58	85.96	1
Drilling and blasting	25.47	13.25	0.76	0.11	0.19	0.11	4
Materials handling	2 010.18	883.82	63.30	8.72	12.78	9.30	2
Crushing and screening	455.00	169.00	31.27	1.97	2.44	4.60	3
Wind erosion	3.98	0.66	0.16	0.02	0.01	0.02	5
TOTAL	**23 063.14**	**6 915.66**	**680.39**	**100.00**	**100.00**	**100.00**	
Mitigated: CE of 75% applied to unpaved roads; 50% applied to crushing activities							
Vehicle entrainment	5 142.13	1 462.24	146.22	69.40	59.82	64.68	1
Drilling and blasting	25.47	13.25	0.76	0.34	0.54	0.34	4
Materials handling	2 010.18	883.82	63.30	27.13	36.16	28.00	2
Crushing and screening	227.50	84.50	15.63	3.07	3.46	6.91	3
Wind erosion	3.98	0.66	0.16	0.05	0.03	0.07	5
TOTAL	**7 409.26**	**2 444.45**	**226.08**	**100.00**	**100.00**	**100.00**	
Mitigated: CE of 90% applied to unpaved roads; 50% applied to crushing activities; 99% to drilling							
Vehicle entrainment	2 056.85	584.89	58.49	47.81	37.59	42.47	1
Drilling and blasting	4.00	2.08	0.12	0.09	0.13	0.09	4
Materials handling	2 010.18	883.82	63.30	46.72	56.80	45.97	2
Crushing and screening	227.50	84.50	15.63	5.29	5.43	11.35	3
Wind erosion	3.98	0.66	0.16	0.09	0.04	0.12	5
TOTAL	**4 302.51**	**1 555.94**	**137.71**	**100.00**	**100.00**	**100.00**	

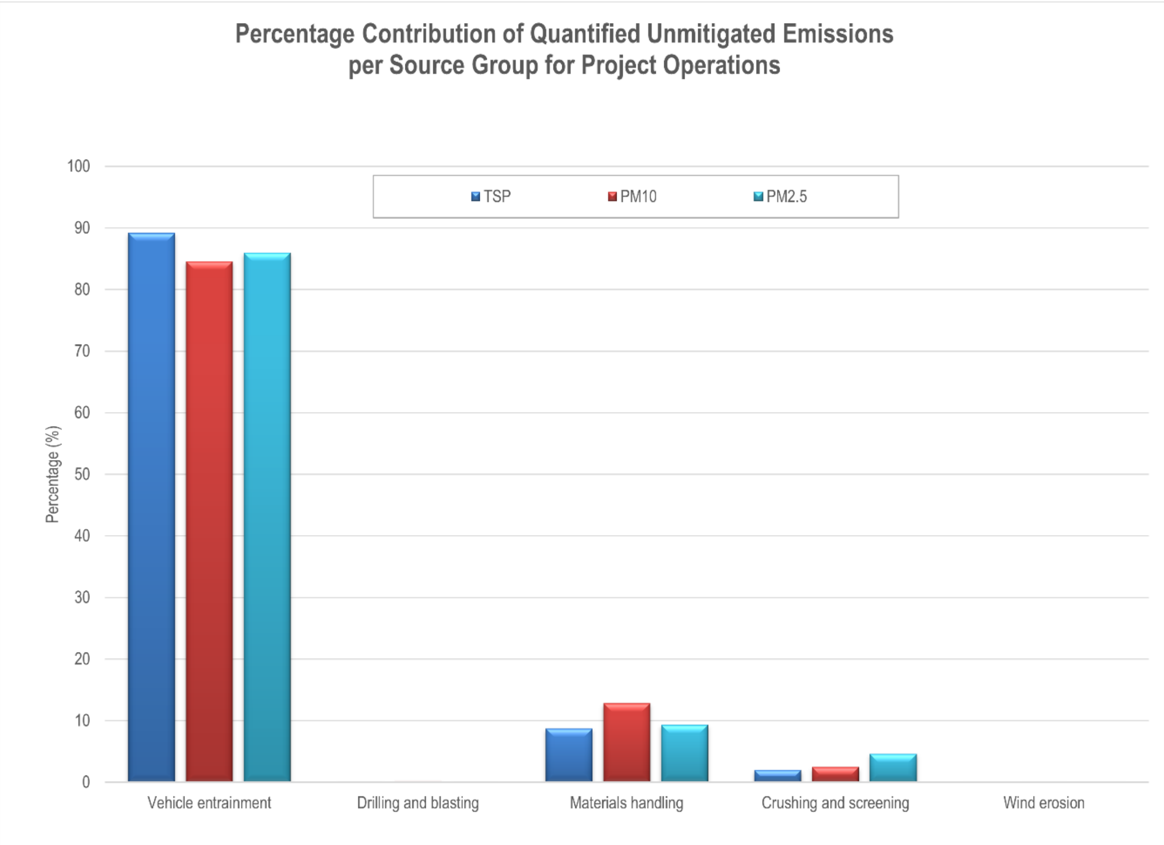

Figure 4-1: Percentage contribution of particulate emissions due to routine unmitigated operations for the proposed project

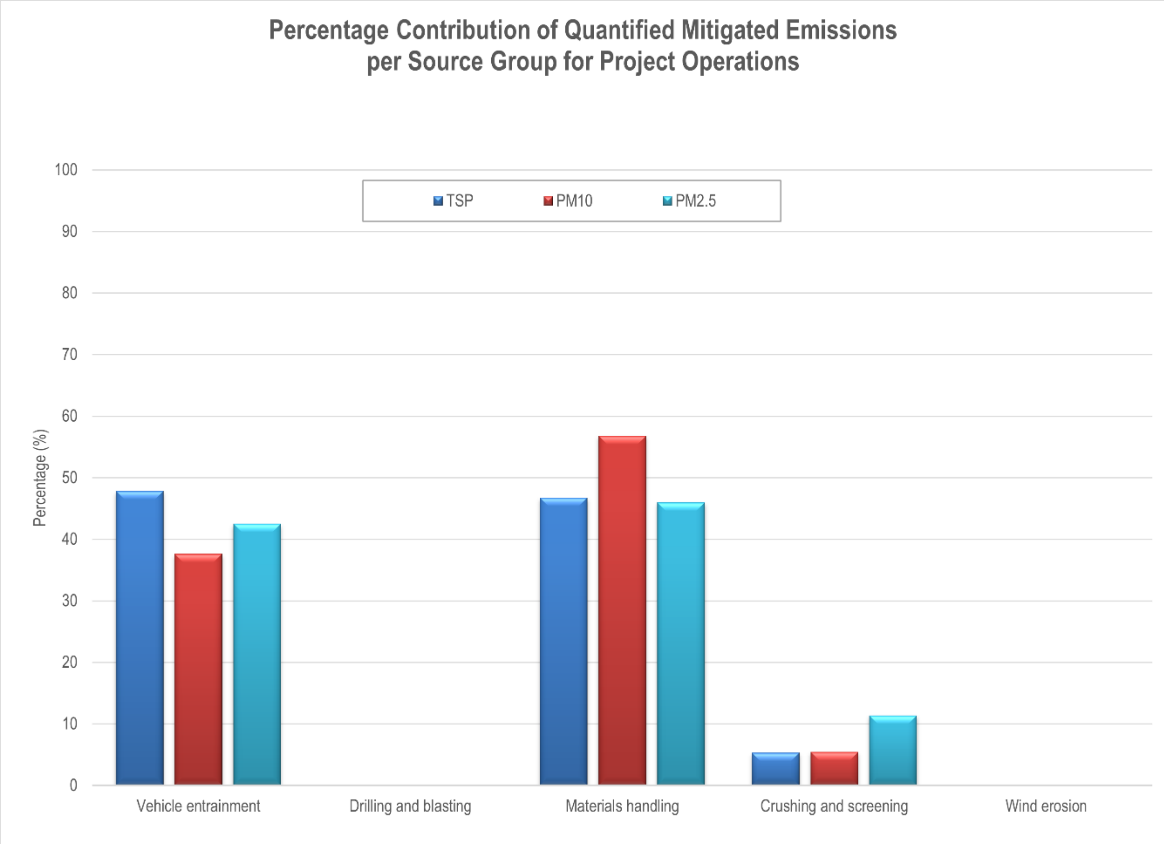

Figure 4-2: Percentage contribution of particulate emissions due to routine mitigated operations for the proposed project (assuming 90% CE on unpaved roads, 50% CE on crushing activities and 99% CE on drilling activities)

4.1.3 Closure and Decommissioning Phase

It is assumed that all the operations will have ceased by the closure phase of the project. The potential for impacts during this phase will depend on the extent of rehabilitation efforts during closure. Aspects and activities associated with the closure phase of the proposed operations are listed in Table 4-6. Simulations of the closure and decommissioning phases were not included in the current study due to its temporary impacting nature.

Table 4-6: Activities and aspects identified for the closure and decommissioning phase

Impact	Source	Activity
PM emissions	WRDs, stockpiles and mine pits	Dust generated during rehabilitation activities
PM emissions	Plant and infrastructure	Demolition of the process plant and infrastructure
Gas emissions	Vehicles	Tailpipe emissions from vehicles utilised during the closure phase

4.2 Atmospheric Dispersion Modelling

The impact assessment of the project's operations on the environment is discussed in this section. To assess impact on human health and the environment the following important aspects need to be considered:

- The criteria against which impacts are assessed (Section 2.4);
- The potential of the atmosphere to disperse and dilute pollutants emitted by the project (Section 3.2); and
- The AQSRs in the vicinity of the proposed mine (Section 3.1).

The impact of proposed operations on the atmospheric environment was determined through the simulation of ambient pollutant concentrations. Dispersion models simulate ambient pollutant concentrations as a function of source configurations, emission strengths and meteorological characteristics, thus providing a useful tool to ascertain the spatial and temporal patterns in the ground level concentrations arising from the emissions of various sources. Increasing reliance has been placed on concentration estimates from models as the primary basis for environmental and health impact assessments, risk assessments and emission control requirements. It is therefore important to carefully select a dispersion model for the purpose.

4.2.1 Dispersion Model Selection

In the calculation of ambient air pollutant concentrations and dustfall rates use was made of the US EPA AERMOD atmospheric dispersion modelling suite. AERMOD is a Gaussian plume model best used for near-field applications where the steady-state meteorology assumption is most likely to apply. AERMOD is a model developed with the support of the AMS/EPA Regulatory Model Improvement Committee (AERMIC), whose objective has been to include state-of the-art science in regulatory models (Hanna, Egan, Purdum, & Wagler, 1999). AERMOD is a dispersion modelling system with three components, namely: AERMOD (AERMIC Dispersion Model), AERMAP (AERMOD terrain pre-processor), and AERMET (AERMOD meteorological pre-processor). AERMET version 22112 and AERMOD version 22112 was used for the assessment.

4.2.2 Meteorological Requirements

Modelled hourly WRF meteorological data for the 1 January 2020 to 31 December 2022 was utilised for the dispersion simulations.

4.2.3 Source Data Requirements

The US EPA AERMOD model is able to model point, jet, area, line and volume sources. Sources were modelled as follows:

- Unpaved roads – modelled as area sources;
- Wind erosion – modelled as area sources;
- Materials handling and crushing and screening – modelled as volume sources; and,
- Drilling activities – modelled as area sources.

4.2.4 Modelling Domain

The dispersion of pollutants expected to arise from proposed activities was modelled for an area covering 26 km (east-west) by 27.5 km (north-south). The area was divided into a grid matrix with a resolution of 200 m by 220 m, with the project located centrally. AERMOD calculates ground-level (1.5 m above ground level) concentrations and dustfall rates at each grid and discrete receptor point.

4.3 Dispersion Modelling Results

Dispersion modelling was undertaken to determine the 99th percentile daily and annual average ground level concentrations. Averaging periods were selected to facilitate the comparison of predicted pollutant concentrations to relevant ambient air quality and inhalation health criteria as well as dustfall regulations.

Pollutants with the potential to result in human health impacts which are assessed in this study include $PM_{2.5}$ and PM_{10}. Dustfall is assessed for its nuisance potential. Results are primarily provided in form of isopleths to present areas of exceedance of assessment criteria. Ground level concentration or dustfall isopleths presented in this section depict interpolated values from the concentrations simulated by AERMOD for each of the receptor grid points specified.

It should also be noted that ambient air quality criteria apply to areas where the Occupational Health and Safety regulations do not apply, thus outside the property or lease area. Ambient air quality criteria are therefore not occupational health indicators but applicable to areas where the general public has access i.e., off-site.

The plots provided for the relevant pollutants of concern during the operational phase are given in Table 4-7.

Table 4-7: Isopleth plots presented in the current section

Pollutant	Operating Conditions	Figure
$PM_{2.5}$	Unmitigated operations	4-3
	Mitigated operations (assuming 75% CE on the unpaved roads and 50% CE on the crushing activities)	4-4
	Mitigated operations (assuming 90% CE on the unpaved roads, 50% CE on the crushing activities and 99% CE on the drilling activities)	4-5
PM_{10}	Unmitigated operations	4-6
	Mitigated operations (assuming 75% CE on the unpaved roads and 50% CE on the crushing activities)	4-7
	Mitigated operations (assuming 90% CE on the unpaved roads, 50% CE on the crushing activities and 99% CE on the drilling activities)	4-8
TSP	Unmitigated operations	4-9
	Mitigated operations (assuming 75% CE on the unpaved roads and 50% CE on the crushing activities)	4-10
	Mitigated operations (assuming 90% CE on the unpaved roads, 50% CE on the crushing activities and 99% CE on the drilling activities)	4-11

The modelled results due to unmitigated project operations indicate that the $PM_{2.5}$ and PM_{10} AQOs are exceeded at the closest AQSRs to the project (i.e., farmstead ~2.5 km to the east and ~3.5 km to the south of the mine boundary). For mitigated project operations, particulate concentrations reduce significantly and $PM_{2.5}$ and PM_{10} AQOs are not exceeded at the closest AQSRs.

The simulated maximum daily dustfall rates for unmitigated and mitigated activities do not exceed the AQO (SA NDCR residential limit of 600 mg/m²/day) at any of the AQSRs off-site.

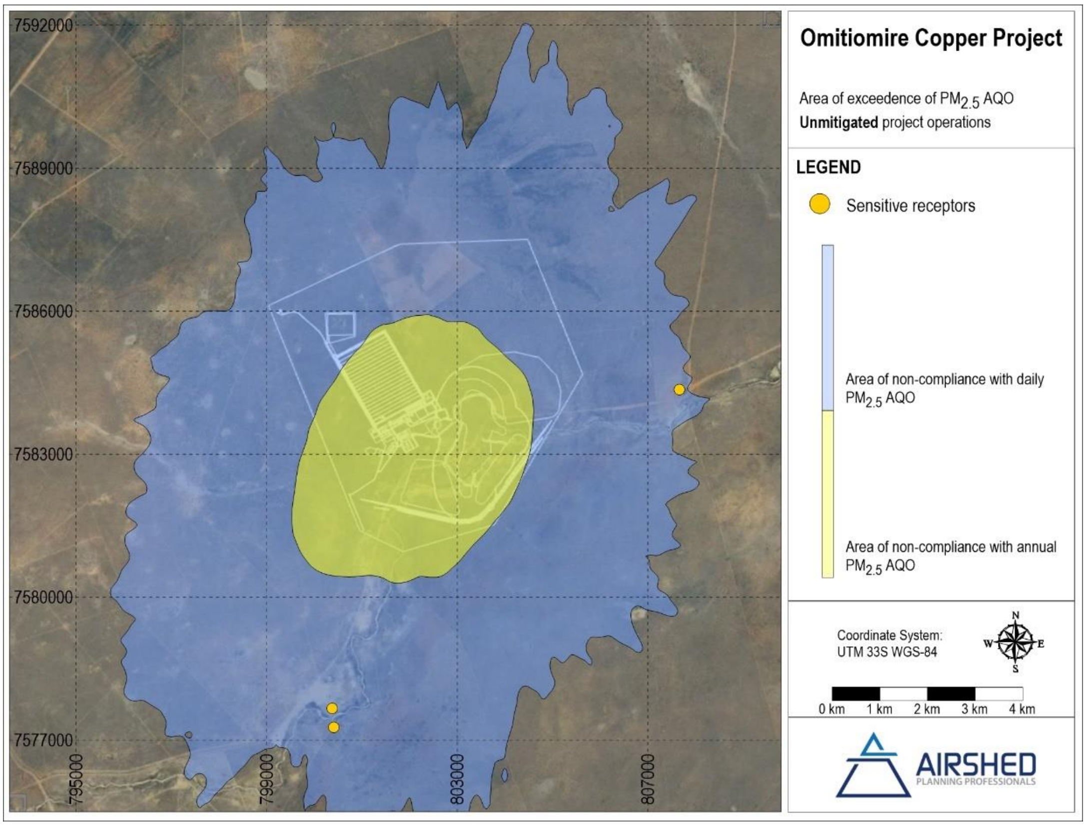

Figure 4-3: Area of exceedance of recommended AQO of $PM_{2.5}$ due to routine unmitigated project operations

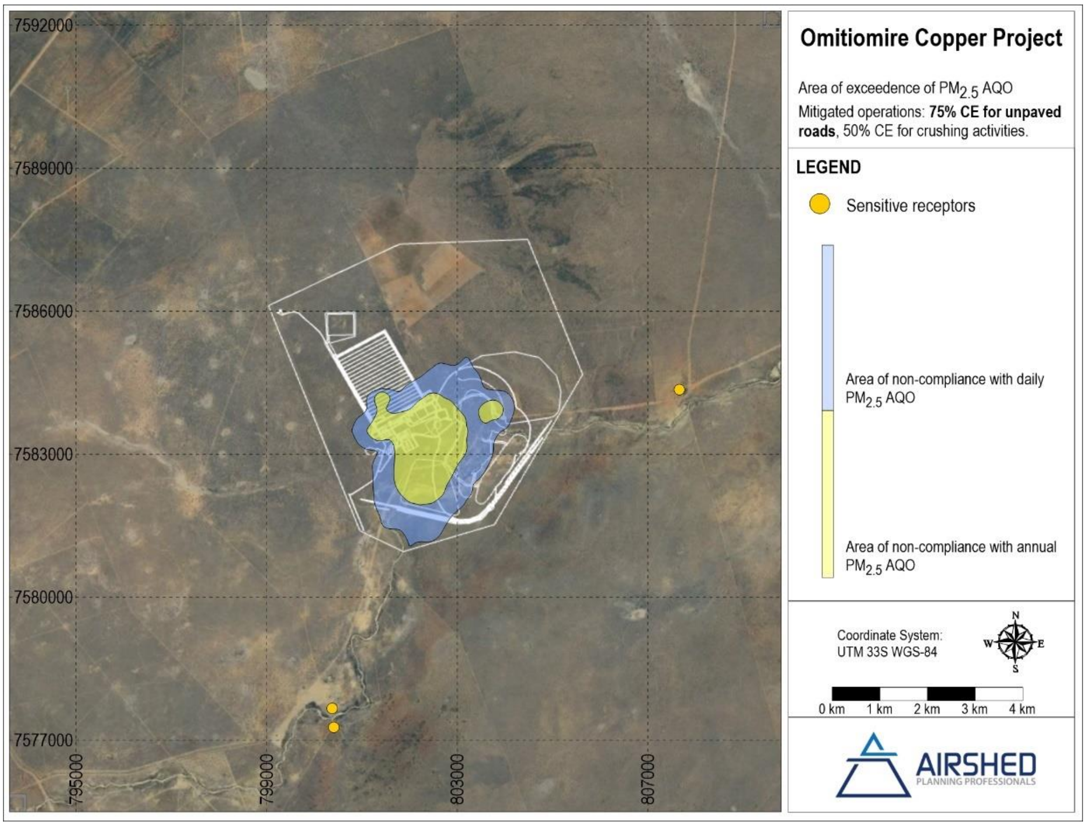

Figure 4-4: Area of exceedance of recommended AQO of $PM_{2.5}$ due to routine mitigated project operations (assuming 75% CE on unpaved roads and 50% CE on crushing activities)

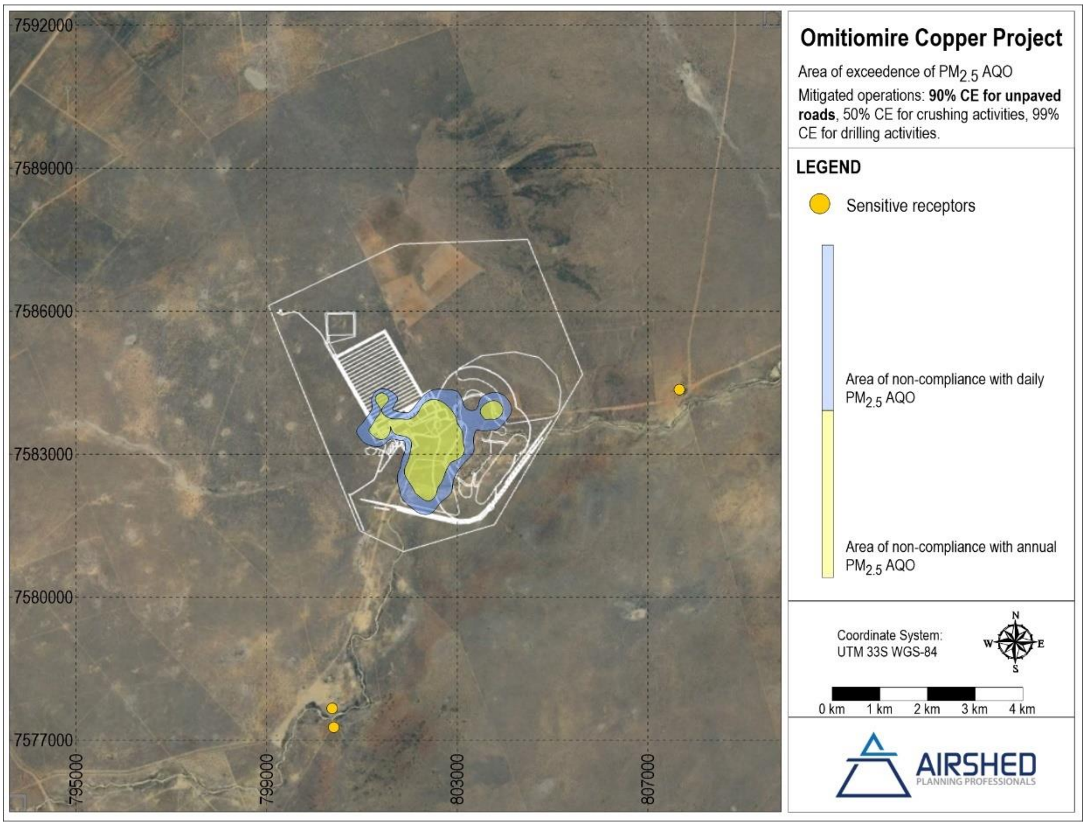

Figure 4-5: Area of exceedance of recommended AQO of $PM_{2.5}$ due to routine mitigated project operations (assuming 90% CE on unpaved roads, 50% CE on crushing activities, and 99% CE on drilling activities)

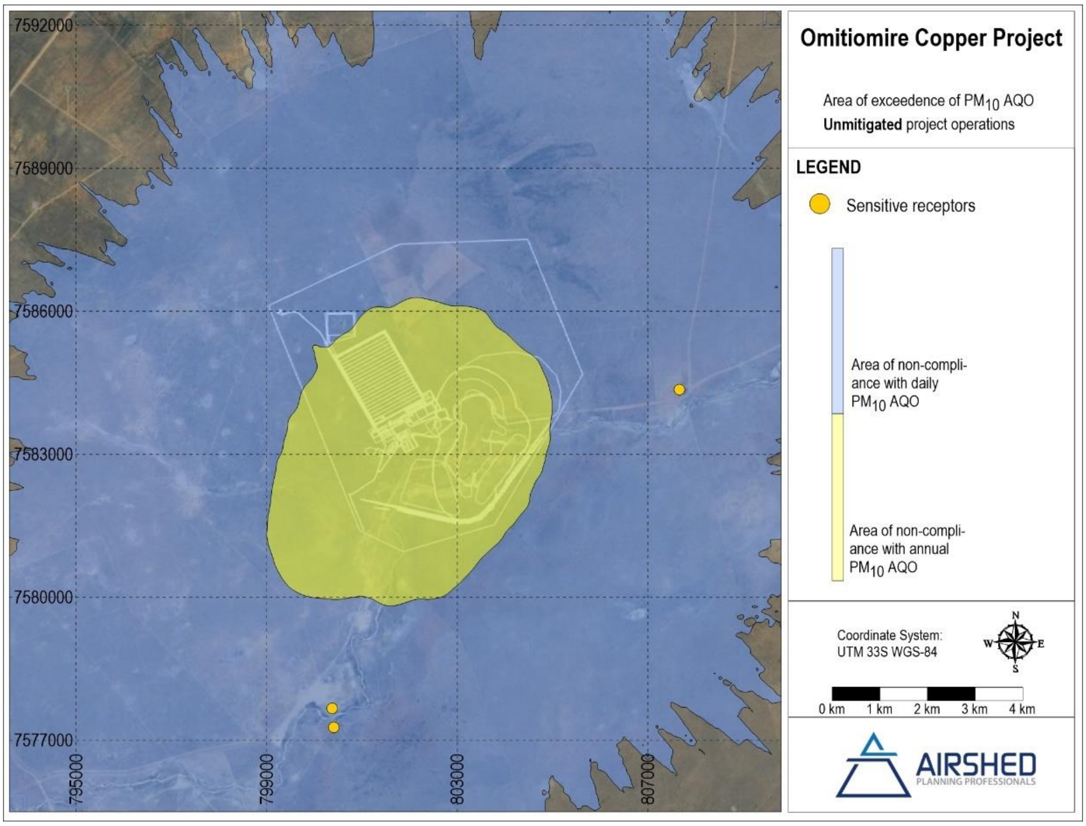

Figure 4-6: Area of exceedance of recommended AQO of PM_{10} due to routine unmitigated project operations

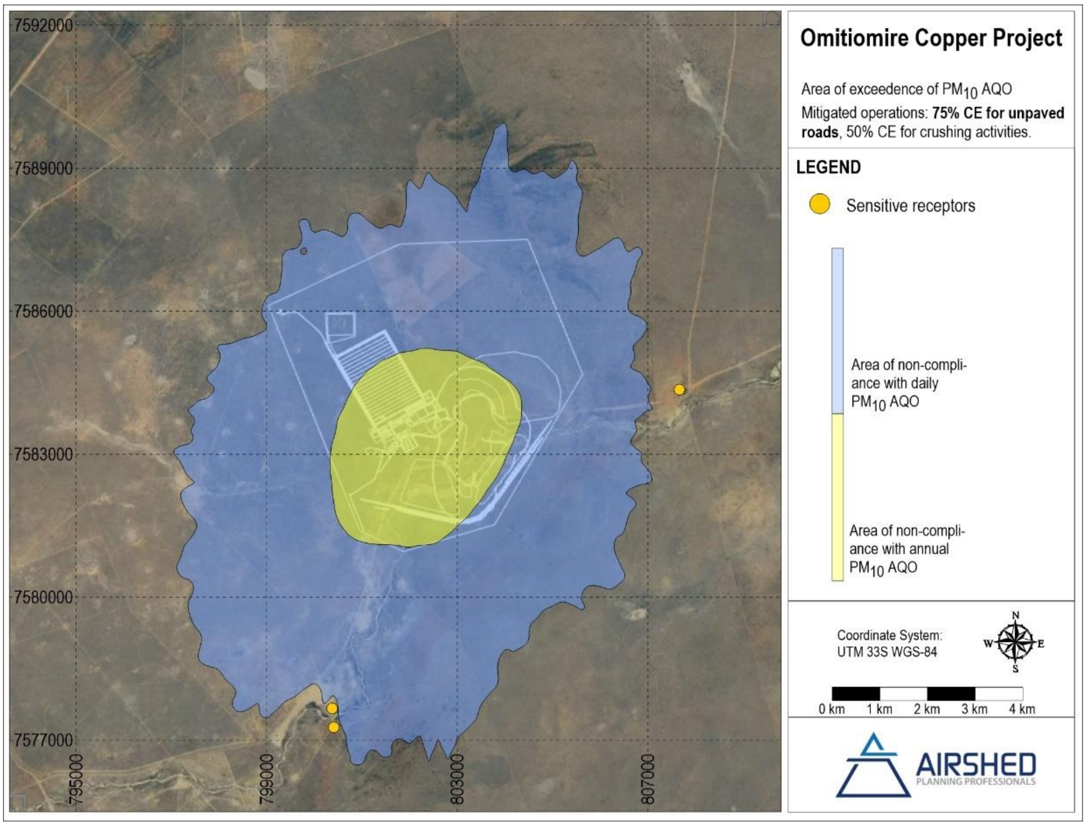

Figure 4-7: Area of exceedance of recommended AQO of PM_{10} due to routine mitigated project operations (assuming 75% CE on unpaved roads and 50% CE on crushing activities)

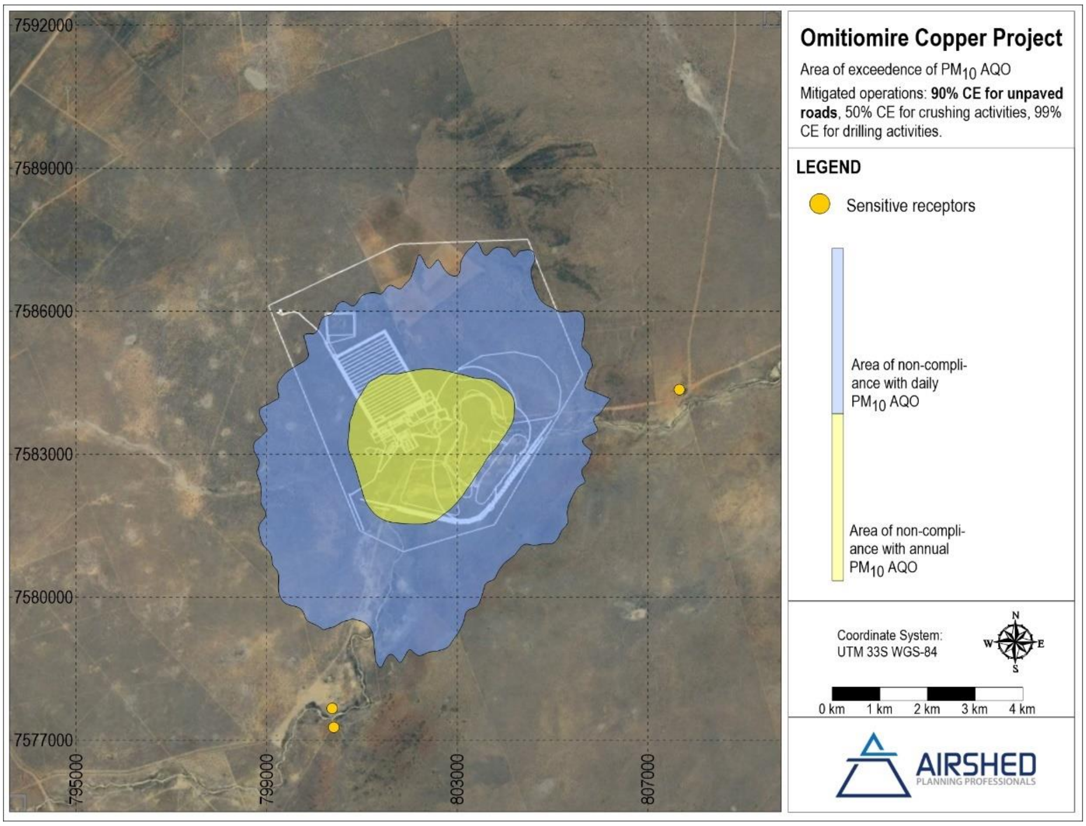

Figure 4-8: Area of exceedance of recommended AQO of PM_{10} due to routine mitigated project operations (assuming 90% CE on unpaved roads, 50% CE on crushing activities, and 99% CE on drilling activities)

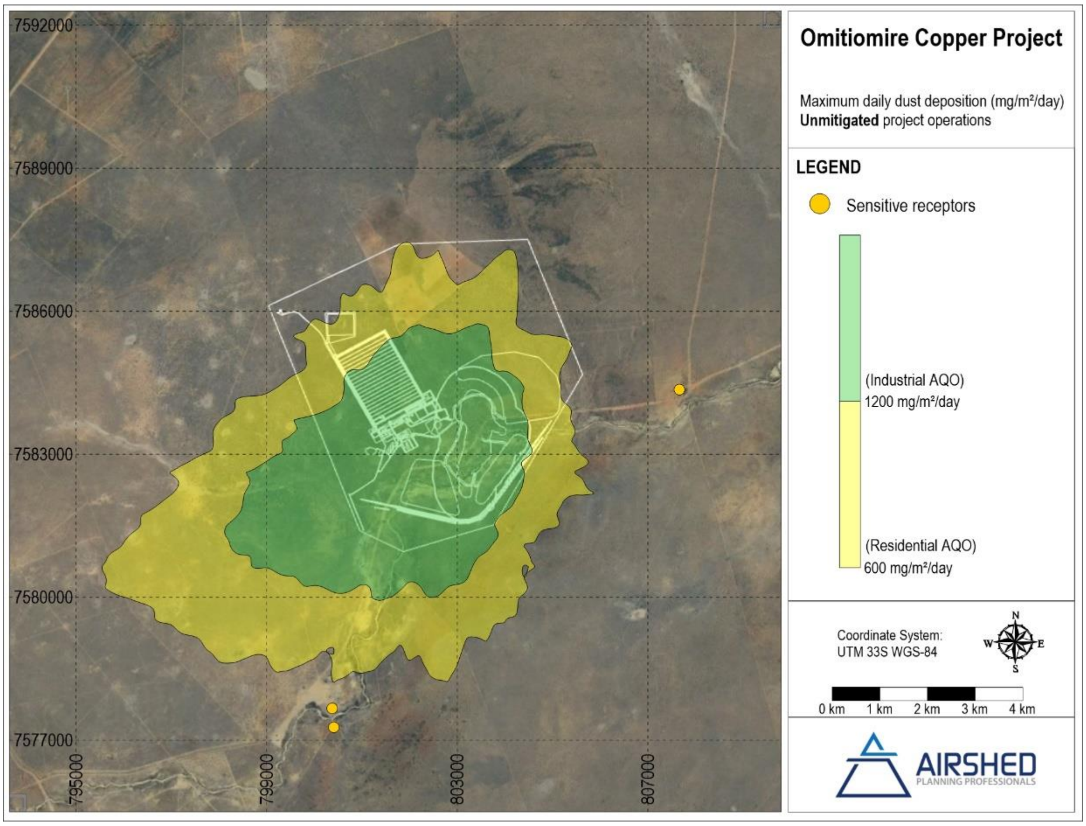

Figure 4-9: Area of exceedance of recommended AQO of dust deposition due to routine unmitigated project operations

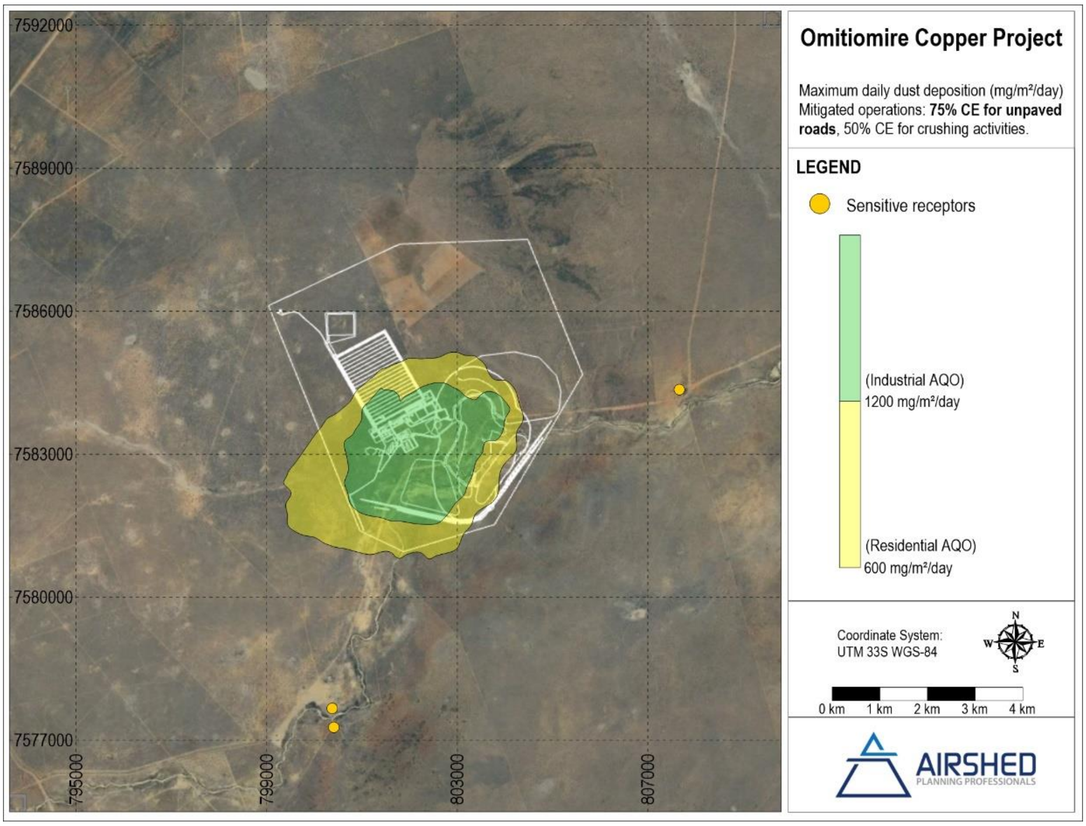

Figure 4-10: Area of exceedance of recommended AQO of dust deposition due to routine mitigated project operations (assuming 75% CE on unpaved roads and 50% CE on crushing activities)

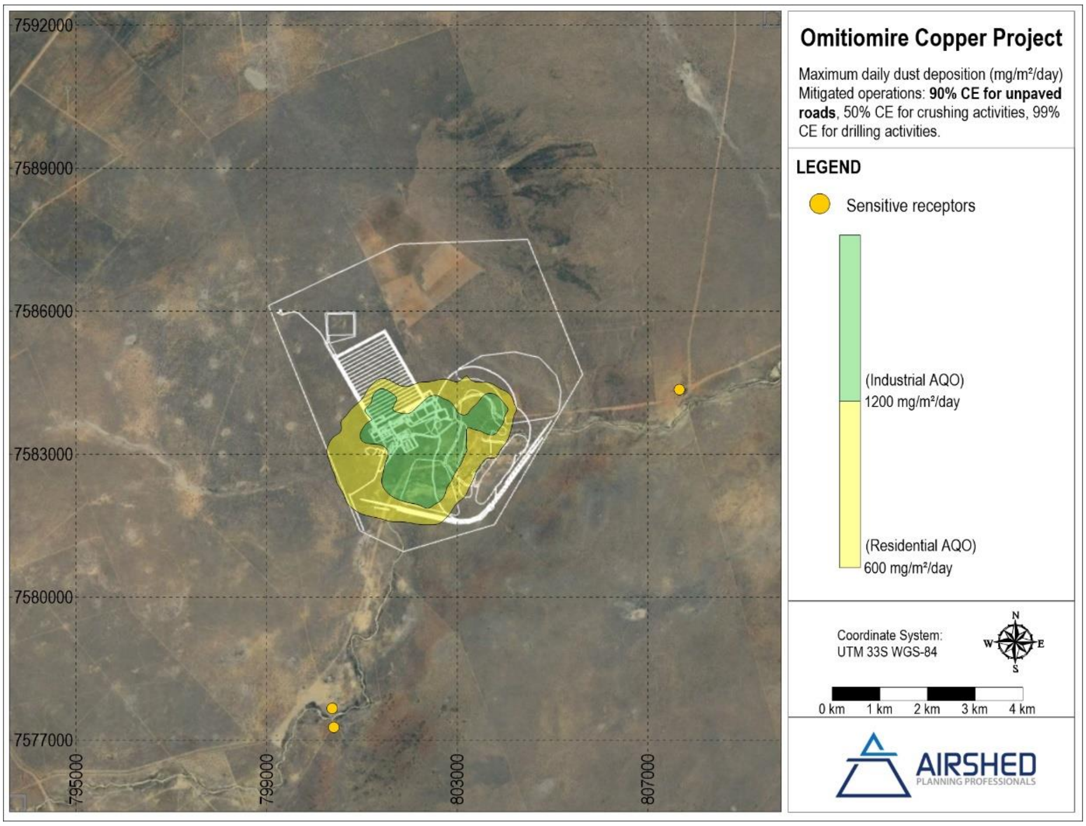

Figure 4-11: Area of exceedance of recommended AQO of dust deposition due to routine mitigated project operations (assuming 90% CE on unpaved roads, 50% CE on crushing activities, and 99% CE on drilling activities)

5 Air Quality Management Measures

In the light of potentially high impacts from the proposed project operations, specifically from PM_{10} and $PM_{2.5}$ concentrations, it is recommended that the project proponent commit to adequate air quality management planning throughout the life of the proposed project. An air quality management plan provides options on the control of PM at the main sources, while the monitoring network is designed to track the effectiveness of the mitigation measures.

Based on the findings of the impact assessment, the following mitigation, management, and monitoring recommendations are proposed following a hierarchy of: **Avoidance > Minimisation > Rehabilitation > Offset**.

5.1 Proposed Mitigation Measures and/or Target Control Efficiencies

The main sources resulting in particulate emissions and impacts from the proposed project was vehicle entrainment on unpaved roads and crushing and screening activities.

5.1.1 Construction and closure phase:

- Air quality impacts during construction would be minimised through basic control measures such as limiting the speed of haul trucks; limit unnecessary travelling of vehicles on untreated roads; reducing the area of construction where it is close to receptors; and to apply water sprays on regularly travelled, unpaved sections.
- During closure and post-closure, the open exposed areas prone to wind erosion should be either covered with surface material and rehabilitated (vegetated or compacted) to ensure the surfaces form a hard crust and/or gladded with waste rock.

5.1.2 Operational phases (the control efficiencies are from NPI, 2012):

In order to minimise off-site impacts the following mitigation measures are recommended:

- For the control of vehicle entrained dust the following is recommended to use chemical suppressants such as *dust-a-side* to ensure a CE of 90%, as indicated by literature to be achievable. The application frequency of the chemical suppressants would depend on the road conditions which in turn is affected by traffic and climate. The road conditions should therefore be closely monitored to determine the frequency of the application to ensure minimal dust generation from the unpaved road surfaces.
- According to the NPI (2012), in minimising dust from crushing and screening operations, water sprays to keep the ore wet should ensure a 50% CE, whereas windbreaks around the crushers could achieve 30% CE. Hooding with cyclones would achieve 65% CE, whereas scrubbers will achieve 75% CE and fabric filters would result in 83% CE. Enclosure or underground crushing would result in up to 100% CE.

5.2 Performance Indicators

Key performance indicators against which progress of implemented mitigation and management measures may be assessed, form the basis for all effective environmental management practices. In the definition of key performance indicators careful attention is usually paid to ensure that progress towards their achievement is measurable, and that the targets set are achievable given available technology and experience.

Performance indicators are usually selected to reflect both the source of the emission directly (source monitoring) and the impact on the receiving environment (ambient air quality monitoring). Ensuring that no visible evidence of windblown dust exists represents an example of a source-based indicator, whereas maintaining off-site dustfall levels, at the identified AQSRs, to below 600 mg/m²-day represents an impact- or receptor-based performance indicator.

Except for vehicle/equipment emission testing, source monitoring at mining activities can be challenging due to the fugitive and wind-dependant nature of particulate emissions. The focus is therefore rather on receptor-based performance indicators i.e., compliance with ambient air quality standards and dustfall regulations.

5.3 Ambient Air Quality Monitoring

Ambient air quality monitoring can serve to meet various objectives, such as:

- Compliance monitoring;
- Validate dispersion model results;
- Use as input for health risk assessment;
- Assist in source apportionment;
- Temporal and spatial trend analysis;
- Source quantification; and,
- Tracking progress made by control measures.

It is recommended that the dustfall monitoring network currently in place for the site, be continued throughout the construction, operation and closure phases of the project, with the exception of AQ02. This sampling site is in the operational layout of the project and will have to be moved (perhaps to the crusher area) once project activities commence. The dustfall units must be maintained and the monthly dustfall results used as indicators to tract the effectiveness of the applied mitigation measures.

The dustfall monitoring network should follow the American Society for Testing and Materials standard method for collection and analysis of dustfall (ASTM D1739-98). The ASTM method covers the procedure of collection of dustfall and its measurement and employs a simple device consisting of a cylindrical container exposed for one calendar month (30 ±2 days). The method provides for a dry bucket, which is advisable in the dry environment.

It is recommended that periodic ambient PM_{10} and $PM_{2.5}$ monitoring at AQSRs downwind of the project (i.e., the farmsteads ~3.5 km to the south of the mine boundary), be undertaken once the project is operational to determine whether the AQOs are being met.

5.4 Periodic Inspections and Audits

Periodic inspections and external audits are essential for progress measurement, evaluation and reporting purposes. It is recommended that site inspections and progress reporting be undertaken at regular intervals (at least quarterly), with annual environmental audits being conducted. Annual environmental audits should be continued at least until closure. Results from site inspections and monitoring efforts should be combined to determine progress against source- and receptor-based performance indicators. Progress should be reported to all interested and affected parties, including authorities and persons affected by pollution.

The criteria to be taken into account in the inspections and audits must be made transparent by way of minimum requirement checklists included in the management plan. Corrective action or the implementation of contingency measures must be proposed to the stakeholder forum in the event that progress towards targets is indicated by the quarterly/annual reviews to be unsatisfactory.

5.5 Liaison Strategy for Communication with I&APs

Stakeholder forums provide possibly the most effective mechanisms for information dissemination and consultation. Management plans should stipulate specific intervals at which forums will be held and provide information on how people will be notified of such meetings. Given the close proximity of the mine to residential housing units, it is recommended that such meetings be scheduled and held at least on a bi-annual basis. A complaints register must be kept at all times.

5.6 Financial Provision

The budget should provide a clear indication of the capital and annual maintenance costs associated with dust control measures, dust monitoring plans and rehabilitation. It may be necessary to make assumptions about the duration of aftercare prior to obtaining closure. This assumption must be made explicit so that the financial plan can be assessed within this framework. Costs related to inspections, audits, environmental reporting and Interested and Affected Parties liaison should also be indicated where applicable. Provision should also be made for capital and running costs associated with dust control contingency measures and for security measures. The financial plan should be audited by an independent consultant, with reviews conducted on an annual basis.

6 FINDINGS AND RECOMMENDATIONS

A quantitative air quality impact assessment was conducted for the operational phase activities of the proposed project. Construction, closure, and post-closure activities were assessed qualitatively. The assessment included an estimation of atmospheric emissions, the simulation of pollutant concentrations and determination of the significance of impacts. The main concern is the potential air quality impacts from the proposed project on the receiving environment and human health.

6.1 Main Findings

6.1.1 Baseline Assessment

The main findings from the baseline assessment can be summarised as follows:

- The main sources likely to contribute to cumulative particulate impact are vehicle entrainment on unpaved road surfaces and wind erosion of open areas.
- The wind field is dominated by winds from the north-east.
- The closest communities are located more than 30 km from the project. The closest potential AQSRs to the project are farmsteads ~2.5 km to the east and ~3.5 km to the south of the mine boundary.
- Measured dust fallout for the period July 2022 to September 2023 was on average 70 mg/m²/day across all sites over the study area, and below the AQOs for dustfall at all sites over the entire sampling period.
- The main pollutant of concern in the region is PM (TSP; PM_{10} and $PM_{2.5}$) resulting from vehicle entrainment on the roads (paved, unpaved and treated surfaces) and windblown dust. Gaseous pollutants such as SO_2, NOx, CO and CO_2 would result from vehicles and combustion sources, but these are expected to be at low concentrations due to the few sources in the region.
- Sources of atmospheric emissions in the vicinity of the proposed project include:
  - Windblown dust: Windblown particulates from natural exposed surfaces, mine waste facilities, and product stockpiles can result in significant dust emissions with high particulate concentrations near the source locations, potentially affecting both the environment and human health. Windblown dust from natural exposed surfaces in and at the project is only likely to result in PM emissions under high wind speed conditions (>10 m/s), and since recorded wind speeds did not exceed 10 m/s, this source is likely to be of low significance.
  - Vehicle entrainment on paved and unpaved roads
  - Regional transport of pollutants: regional-scale transport of mineral dust and ozone (due to vegetation burning) from the north of Namibia is a significant contributing source to background PM concentrations.

6.1.2 Impact Assessment

The findings from the impact assessment can be summarised as follows:

- **Construction** normally comprises a series of different operations including land clearing, topsoil removal, road grading, material loading and hauling, stockpiling, grading, bulldozing, compaction, etc., with PM the main pollutants of concern from these activities. The extent of dust emissions would vary substantially from day to day depending on the level of activity, the specific operations, and the prevailing meteorological conditions, and how close these activities are to AQSRs. Due to the intermittent nature of construction operations, the emissions are expected to have a varying impact depending on the level of activity. With mitigation measures in place these impacts are expected to be low.

- **Operational Phase:**
  - Emissions quantified for the proposed project were restricted to fugitive releases (non-point releases) with particulates the main pollutant of concern. Gaseous emissions (i.e., SO_2, NO_x, CO and VOCs) will primarily result from diesel combustion. The gaseous impacts are expected to be localised.
  - Both unmitigated and mitigated scenarios were modelled. Mitigation that was applied was based on design mitigation measures provided, which included the following:
    - Surface haul roads: water sprays resulting in 75% CE;
    - Surface haul roads: chemical suppressants resulting in 90% CE;
    - Crushing and screening of ROM (primary; secondary and tertiary): resulting in 50% CE from water sprays to keep ore wet.
    - Drilling activities: fabric filters resulting in 99% CE.
  - Dispersion modelling results for unmitigated project operations indicate off-site exceedances of the AQOs for $PM_{2.5}$, PM_{10} at the closest AQSRs (i.e., ~2.5 km to the east and ~3.5 km to the south of the mine boundary).
  - Dispersion modelling results for mitigated project operations indicate no off-site exceedances of the AQOs for $PM_{2.5}$, PM_{10} at the closest AQSRs.
  - Maximum dust deposition due to unmitigated and mitigated project operations does not indicate exceedances of AQOs at the closest off-site AQSRs. Cumulative air quality impacts could not be assessed since no background PM_{10} and $PM_{2.5}$ data are available. The localised PM_{10} and $PM_{2.5}$ impacts from the proposed project modelling results indicate the potential for low regional cumulative impacts, and only high cumulative impacts in the immediate vicinity of the mine. Off-site impacts are likely to be managed with proper mitigation measures in place.
- **Closure** operations are likely to include demolishing existing structures, scraping and moving surface material to cover the remaining exposed surfaces (WRDs) and contouring of the surface areas. The impacts are expected to be similar to that of construction operations – potentially small but harmful impacts at nearby receptors, depending on the level of activity but low impacts with mitigation measures in place. **Post-closure** operations, likely to include vegetation cover maintenance, would result in very low air quality related impacts.

6.2 Conclusion

The proposed project is likely to result in increased $PM_{2.5}$ and PM_{10} ground level in the immediate vicinity of the mine and impacts can be reduced by applying appropriate mitigation measures. The dispersion modelling results indicate that the $PM_{2.5}$ and PM_{10} AQOs may be exceeded at AQSRs off-site for unmitigated project operations. For mitigated project operations, $PM_{2.5}$ and PM_{10} AQOs are not exceeded at off-site AQSRs. Dustfall rates are likely to be within AQO at off-site AQSRs throughout the life of the project, with gaseous concentrations (SO_2, NO_2 and CO) expected to result in low air quality impacts.

It is the specialist's opinion that the proposed project could be authorised provided strict enforcement of mitigation measures and the tracking of the effectiveness of these measures to ensure the lowest possible off-site impacts.

6.3 Recommendations

Based on the findings from the air quality impact assessment for the project following recommendations are included:

- Construction and closure phases:
  - Air quality impacts during construction would be reduced through basic control measures such as limiting the speed of haul trucks; limit unnecessary travelling of vehicles on untreated roads; and applying dust-a-side on regularly travelled, unpaved sections.
  - When haul trucks need to use public roads, the vehicles need to be cleaned of all mud and the material transported must be covered to minimise windblown dust.
- Operational phases:
  - For the control of vehicle entrained dust a CE of 90% on unpaved surface roads through the application of chemical surfactants is recommended.
  - In controlling dust from crushing and screening operations, it is recommended that water sprays be applied to keep the ore wet, to achieve a CE of up to 50%.
- Air Quality Monitoring:
  - It is recommended that the current dustfall monitoring network be continued, with the relocation of dust bucket AQ02. The dustfall units must be maintained and the monthly dustfall results used as indicators to tract the effectiveness of the applied mitigation measures. Dustfall collection should follow the ASTM method.
  - It is further recommended that the dustfall monitoring network be supplemented by periodic ambient PM_{10} and $PM2_{.5}$ monitoring to determine whether the AQO are being met.

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APPENDIX A – SPECIALIST CURRICULUM VITAE

FULL CURRICULUM VITAE

Name of Firm	Airshed Planning Professionals (Pty) Ltd
Name of Staff	Reneé von Gruenewaldt (*nee* Thomas)
Profession	Air Quality and Environmental Noise Scientist
Position	Principal consultant
Date of Birth	13 May 1978
Years with Firm	Since January 2002
Nationalities	South African

MEMBERSHIP OF PROFESSIONAL SOCIETIES

- Registered Professional Natural Scientist (Registration Number 400304/07) with the South African Council for Natural Scientific Professions (SACNASP)
- Member of the National Association for Clean Air (NACA)

KEY QUALIFICATIONS

Reneé von Gruenewaldt (Air Quality Scientist): Reneé joined Airshed Planning Professionals (Pty) Ltd (previously known as Environmental Management Services cc) in 2002. She has, as a Specialist, attained over twenty (20) years of experience in the Earth and Natural Sciences sector in the field of Air Quality and nine (9) years of experience in the field of environmental noise assessments. As an environmental practitioner, she has provided solutions to both large-scale and smaller projects within the mining, minerals, and process industries.

She has developed technical and specialist skills in various air quality modelling packages including the AMS/EPA Regulatory Models (AERMOD and AERMET), UK Gaussian plume model (ADMS), EPA Regulatory puff-based model (CALPUFF and CALMET), puff-based HAWK model and line-based models, Lagrangian GRAL model. Her experience with air emission models includes Tanks 4.0 (for the quantification of tank emissions), WATER9 (for the quantification of wastewater treatment works) and GasSim (for the quantification of landfill emissions). Noise propagation modelling proficiency includes CONCAWE, South African National Standards (SANS 10210) for calculating and predicting road traffic noise and CadnaA for propagation of industrial, road and rail noise sources.

Having worked on projects throughout Africa (i.e., South Africa, Mozambique, Malawi, Kenya, Angola, Democratic Republic of Congo, Namibia, Madagascar and Egypt for Air Quality Impact Assessments and Mozambique, Namibia, Botswana, Kenya, Ghana, Suriname and Afghanistan for Environmental Noise Impact Assessments) Reneé has developed a broad experience base. She has a good understanding of the laws and regulations associated with ambient air quality and emission limits in South Africa and various other African countries, as well as the World Bank Guidelines, European Community Limits and World Health Organisation.

RELEVANT EXPERIENCE (AIR QUALITY)

Mining and Ore Handling

Reneé has undertaken numerous air quality impact assessments and management plans for coal, platinum, uranium, copper, cobalt, chromium, fluorspar, bauxite, manganese and mineral sands mines. These include: compilation of emissions databases for Landau and New Vaal coal collieries (SA), impact assessments and management plans for numerous mines over Mpumalanga (viz. Schoonoord, Belfast, Goedgevonden, Mbila, Evander South, Driefontein, Hartogshoop, Belfast, New Largo, Geluk, etc.), Mmamabula Coal Colliery (Botswana), Moatize Coal Colliery (Mozambique), Revuboe Coal Colliery (Mozambique), Toliera Sands Heavy Minerals Mine and Processing (Madagascar), Corridor Sands Heavy Minerals Mine monitoring assessment, El Burullus Heavy Minerals Mine and processing (Egypt), Namakwa Sands Heavy Minerals Mine (SA), Tenke Copper Mine and Processing Plant (DRC), Rössing Uranium (Namibia), Lonmin platinum mines including operations at Marikana, Baobab, Dwaalkop and Doornvlei (SA), Impala Platinum (SA), Pilannesburg Platinum (SA), Aquarius Platinum, Hoogland Platinum Mine (SA), Tamboti PGM Mine (SA), Sari Gunay Gold Mine (Iran), chrome mines in the Steelpoort Valley (SA), Mecklenburg Chrome Mine (SA), Naboom Chrome Mine (SA), Kinsenda Copper Mine (DRC), Kassinga Mine (Angola) and Nokeng Flourspar Mine (SA), etc.

Mining monitoring reviews have also been undertaken for Optimum Colliery's operations near Hendrina Power Station and Impunzi Coal Colliery with a detailed management plan undertaken for Morupule (Botswana) and Glencor (previously known as Xstrata Coal South Africa).

Air quality assessments have also been undertaken for mechanical appliances including the Durban Coal Terminal and Nacala Port (Mozambique) as well as rail transport assessments including BHP-Billiton Bauxite transport (Suriname), Nacala Rail Corridor (Mozambique and Malawi), Kusile Rail (SA) and WCL Rail (Liberia).

Metal Recovery

Air quality impact assessments have been carried out for Highveld Steel, Scaw Metals, Lonmin's Marikana Smelter operations, Saldanha Steel, Tata Steel, Afro Asia Steel and Exxaro's Manganese Pilot Plant Smelter (Pretoria).

Chemical Industry

Comprehensive air quality impact assessments have been completed for NCP (including Chloorkop Expansion Project, Contaminated soils recovery, C3 Project and the 200T Receiver Project), Revertex Chemicals (Durban), Stoppani Chromium Chemicals, Foskor (Richards Bay), Straits Chemicals (Coega), Tenke Acid Plant (DRC), and Omnia (Sasolburg).

Petrochemical Industry

Numerous air quality impact assessments have been completed for Sasol (including the postponement/exemption application for Synfuels, Infrachem, Natref, MIBK2 Project, Wax Project, GTL Project, re-commissioning of boilers at Sasol Sasolburg and Ekandustria), Engen Emission Inventory Functional Specification (Durban), Sapref refinery (Durban), Sasol (at Elrode) and Island View (in Durban) tanks quantification, Petro SA and Chevron (including the postponement/exemption application).

Pulp and Paper Industry

Air quality studies have been undertaken or the expansion of Mondi Richards Bay, Multi-Boiler Project for Mondi Merebank (Durban), impact assessments for Sappi Stanger, Sappi Enstra (Springs), Sappi Ngodwana (Nelspruit) and Pulp United (Richards Bay).

Power Generation

Air quality impact assessments have been completed for numerous Eskom coal fired power station studies including the ash expansion projects at Kusile, Kendal, Hendrina, Kriel and Arnot; Fabric Filter Plants at Komati, Grootvlei, Tutuka, Lethabo and Kriel Power Stations; the proposed Kusile, Medupi (including the impact assessment for the Flue Gas Desulphurization) and Vaal South Power Stations. Reneé was also involved and the cumulative assessment of the existing and return to service Eskom power stations assessment and the optimization of Eskom's ambient air quality monitoring network over the Highveld.

In addition to Eskom's coal fired power stations, various Eskom nuclear power supply projects have been completed including the air quality assessment of Pebble Bed Modular Reactor and nuclear plants at Duynefontein, Bantamsklip and Thyspunt.

Apart from Eskom projects, power station assessments have also been completed in Kenya (Rabai Power Station) and Namibia (Paratus Power Plant).

Waste Disposal

Air quality impact assessments, including odour and carcinogenic and non-carcinogenic pollutants were undertaken for the Waste Water Treatment Works in Magaliesburg, proposed Waterval Landfill (near Rustenburg), Tutuka Landfill, Mogale General Waste Landfill (adjacent to the Leipardsvlei Landfill), Cape Winelands District Municipality Landfill, the Tsoeneng Landfill (Lesotho) and the FG Landfill (near the Midstream Estate). Air quality impact assessments have also been completed for the BCL incinerator (Cape Town), the Ergo Rubber Incinerator and the Ecorevert Pyrolysis Plant.

Cement Manufacturing

Impact assessments for ambient air quality have been completed for the Holcim Alternative Fuels Project (which included the assessment of the cement manufacturing plants at Ulco and Dudfield as well as a proposed blending platform in Roodepoort).

Management Plans

Reneé undertook the quantification of the baseline air quality for the first declared Vaal Triangle Airshed Priority Area. This included the establishment of a comprehensive air pollution emissions inventory, atmospheric dispersion modelling, focusing on impact area "hotspots" and quantifying emission reduction strategies. The management plan was published in 2009 (Government Gazette 32263).

Reneé has also been involved in the Provincial Air Quality Management Plan for the Limpopo Province.

RELEVANT EXPERIENCE (NOISE)

Mining

Reneé has undertaken numerous environmental noise assessments for mining operations. These include environmental noise impact assessments including baseline noise surveys for numerous coal, platinum, manganese, tin and zinc mines. Projects include, but are not limited to, Balama (Mozambique), Masama Coal (Botswana), Lodestone (Namibia), Osino (Namibia), Kurmuk (Ethiopia), Gamsberg (SA), Prieska (SA), Kolomela (SA), Heuningkranz (SA), Syferfontein (SA), South 32 (SA), Mamatwan (SA), Alexander (SA) and Marula Platinum Mine (SA), etc.

Power Generation

Environmental noise assessments have been completed for numerous Eskom coal fired power station studies in SA including the Kriel Fabric Filter Plant, Kendal ash facility, Medupi ash facility. Apart from Eskom projects, power plant assessments have also been completed in Botswana (Morupule), Kenya (Or Power geothermal power plants), Suriname (EBS power plant) and SA (Richards Bay combined cycle power plant).

Process Operations

Environmental noise assessments have been undertaken for various process operations including waste disposal facilities (Bon Accord in Gauteng), bottling and drink facilities (Imali and Isanti Project in Gauteng) and Smelter (Gamsberg in Northern Cape).

Transport

An environmental noise assessment was completed for the Obetsebi road expansion and flyover project in Ghana, the Scorpion Zinc Mine transport route in Namibia and the Sisian-Kajaran (North-South Corridor) Road Project in Armenia.

Gas Pipelines

An environmental noise assessment was completed for the Sheberghan gas pipeline in Afghanistan.

Baseline Noise Surveys

Baseline noise surveys have been undertaken for numerous mining and process operation activities (including Raumix quarries, Kolomela and Sibanye Stillwater Platinum Mines (SA)) in support of onsite Environmental Management Programmes.

OTHER EXPERIENCE (2001)

Research for B.Sc Honours degree was part of the “Highveld Boundary Layer Wind” research group and was based on the identification of faulty data from the Majuba Sodar. The project was THRIP funded and was a joint venture with the University of Pretoria, Eskom and Sasol (2001).

EDUCATION

M.Sc Earth Sciences	University of Pretoria, RSA, Cum Laude (2009) Title: *An Air Quality Baseline Assessment for the Vaal Airshed in South Africa*
B.Sc Hons. Earth Sciences	University of Pretoria, RSA, Cum Laude (2001) Environmental Management and Impact Assessments
B.Sc Earth Sciences	University of Pretoria, RSA, (2000) Atmospheric Sciences: Meteorology

ADDITIONAL COURSES

CALMET/CALPUFF	Presented by the University of Johannesburg, RSA (March 2008)
Air Quality Management	Presented by the University of Johannesburg, RSA (March 2006)
ARCINFO	GIMS, Course: Introduction to ARCINFO 7 (2001)

COUNTRIES OF WORK EXPERIENCE

South Africa, Mozambique, Botswana, Ghana, Suriname, Afghanistan, Malawi, Liberia, Kenya, Angola, Democratic Republic of Congo, Ethiopia, Afghanistan, Lesotho, Namibia, Madagascar, Egypt, Suriname and Iran.

EMPLOYMENT RECORD

January 2002 - Present

Airshed Planning Professionals (Pty) Ltd, (previously known as Environmental Management Services cc until March 2003), Principal Air Quality and Environmental Noise Scientist, Midrand, South Africa.

2001

University of Pretoria, Demi for the Geography and Geoinformatics department and a research assistant for the Atmospheric Science department, Pretoria, South Africa.

Department of Environmental Affairs and Tourism, assisted in the editing of the Agenda 21 document for the world summit (July 2001), Pretoria, South Africa.

1999 - 2000

The South African Weather Services, vacation work in the research department, Pretoria, South Africa.

CONFERENCE AND WORKSHOP PRESENTATIONS AND PAPERS

- Understanding the Synoptic Systems that lead to Strong Easterly Wind Conditions and High Particulate Matter Concentrations on The West Coast of Namibia, H Liebenberg-Enslin, R von Gruenewaldt, H Rauntenbach and L Burger. National Association for Clean Air (NACA) conference, October 2017.
- Topographical Effects on Predicted Ground Level Concentrations using AERMOD, R.G. von Gruenewaldt. National Association for Clean Air (NACA) conference, October 2011.
- Emission Factor Performance Assessment for Blasting Operations, R.G. von Gruenewaldt. National Association for Clean Air (NACA) conference, October 2009.
- Vaal Triangle Priority Area Air Quality Management Plan – Baseline Characterisation, R.G. Thomas, H Liebenberg-Enslin, N Walton and M van Nierop. National Association for Clean Air (NACA) conference, October 2007.
- A High-Resolution Diagnostic Wind Field Model for Mesoscale Air Pollution Forecasting, R.G. Thomas, L.W. Burger, and H Rautenbach. National Association for Clean Air (NACA) conference, September 2005.
- Emissions Based Management Tool for Mining Operations, R.G. Thomas and L.W. Burger. National Association for Clean Air (NACA) conference, October 2004.
- An Investigation into the Accuracy of the Majuba Sodar Mixing Layer Heights, R.G. Thomas. Highveld Boundary Layer Wind Conference, November 2002.

LANGUAGES

	Speak	Read	Write
English	Excellent	Excellent	Excellent
Afrikaans	Fair	Fair	Fair

CERTIFICATION

I, the undersigned, certify that to the best of my knowledge and belief, these data correctly describe me, my qualifications, and my experience.

________________________ 14/07/2023 ________________

Signature of staff member Date (Day / Month / Year)

Full name of staff member: Reneé Georgeinna von Gruenewaldt

Appendix B – Declaration of Independence

DECLARATION OF INDEPENDENCE - PRACTITIONER

Name of Practitioner: Reneé von Gruenewaldt
Name of Registration Body: South African Council for Natural Scientific Professions
Professional Registration No.: 400304/07

Declaration of independence and accuracy of information provided:
Air Quality Impact Assessment for the Proposed Mining Activities on ML 197 for the Omitiomire Copper Project, Khomas Region, Namibia.

I, René von Gruenewaldt, declare that I am independent of the applicant. I have the necessary expertise to conduct the assessments required for the report and will perform the work relating the application in an objective manner, even if this results in views and findings that are not favourable to the applicant. I will disclose to the applicant and the air quality officer all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the air quality officer. The additional information provided in this atmospheric impact report is, to the best of my knowledge, in all respects factually true and correct. I am aware that the supply of false or misleading information to an air quality officer is a criminal offence in terms of section 51(1)(g) of this Act.

Signed at Pretoria on this 29th of November 2023

SIGNATURE
Principal Noise Scientist
CAPACITY OF SIGNATORY

APPENDIX C – COMPARISON OF METEOROLOGICAL DATA

Omitiomire have an onsite meteorological station. Data for the period 2023 was provided for the assessment.

A comparison of wind roses from the WRF data (Figure C-1) to the measured onsite meteorological data (Figure C-2) is provided below. The measured wind direction at the on-site station has a higher frequency of winds from the east and southeast than the WRF data. This may result in an underprediction of impacts to the west and northwest of the project. The overall wind speed from the measured on-site station is also lower than the modelled WRF data set. The simulated impacts may thus be slightly underpredicted closer to site and lightly overpredicted further from the project.

The limitations to the onsite meteorological station data, however, include the sampling of wind direction from only 16 cardinal directions. The predominant wind directions are, thus, likely to be "smoothed out" if wind direction were measured in degrees. The wind speeds are also only sampled at whole numbers making the interval resolution quite course.

The course resolution of the on-site wind direction (16 cardinal wind directions) and the wind speed intervals (provided in whole integers in kilometres per hour), may have resulted in the high recorded calm conditions (34.81%) for the site (which has potentially been overestimated). The Aermod dispersion model cannot model calm conditions. The high calm conditions of 34.81% will thus effectively decrease the overall data availability of 95% for the area to below the recommended 80% required for dispersion modelling purposes. The modelled WRF data was therefore used for the dispersion modelling for the current assessment.

It is recommended that the percentage calm conditions on the onsite meteorological station be investigated through site inspection to make sure the station is correctly sited (with no obstacles in close proximity to the site that may hinder the air flow in the area). The parameters for the on-site station also need to be set up to measure the wind direction in degrees and to measure wind speed (preferably in metres per second) with finer interval resolution. This will improve the overall resolution of the data which could then be used for dispersion modelling purposes.

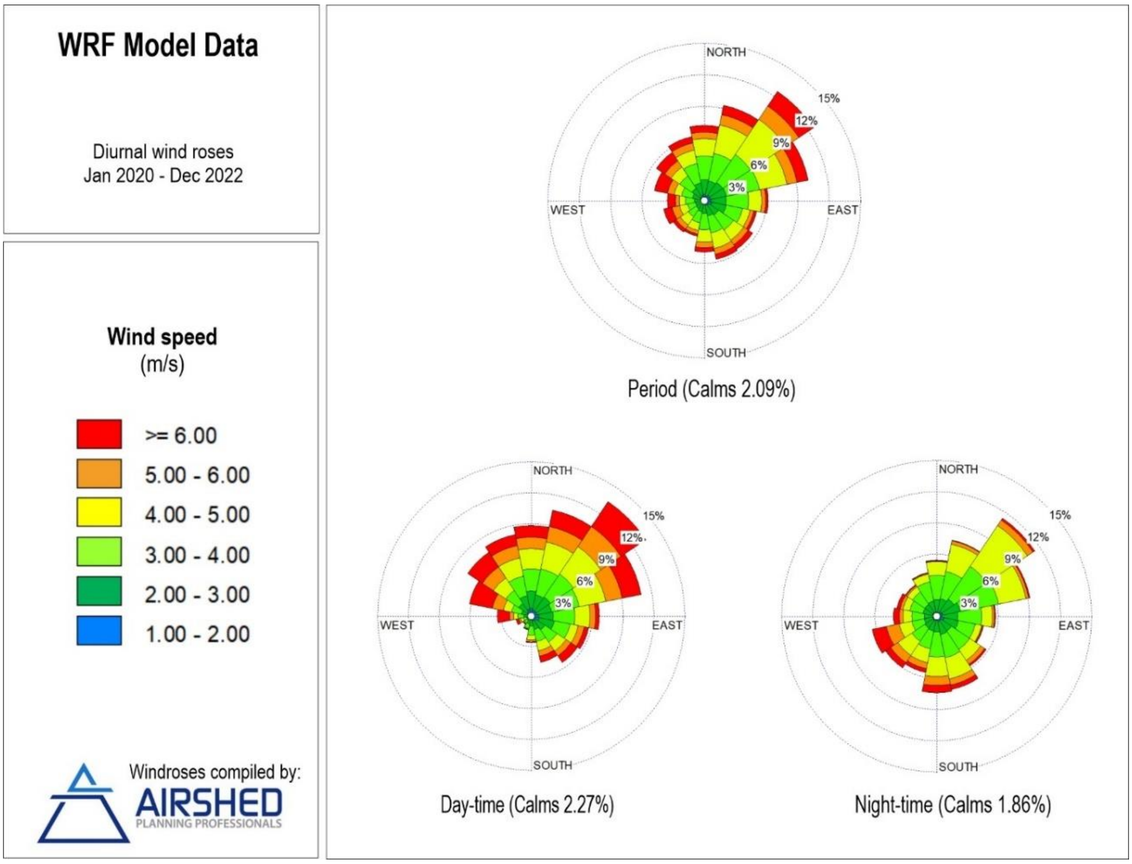

Figure C-1: Period, day- and night-time wind roses for the period 2020-2022 as obtained from the modelled WRF data

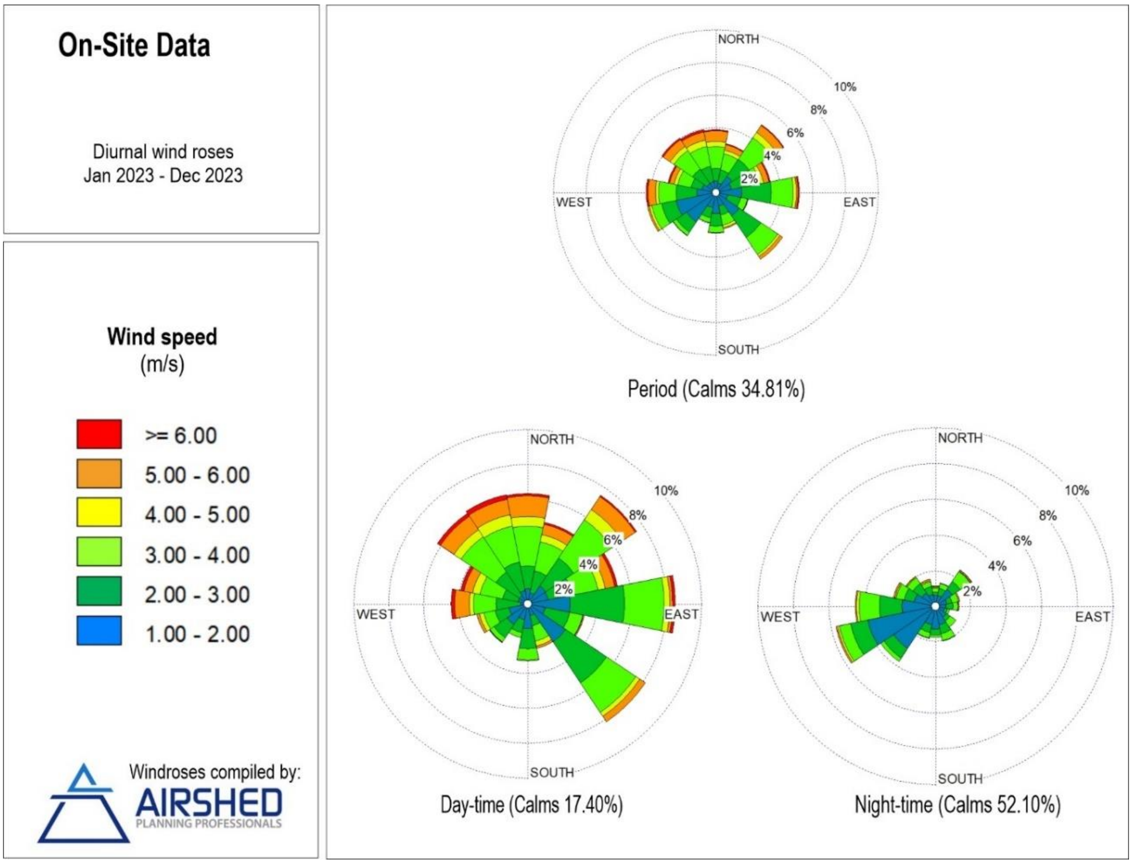

Figure C-2: Period, day- and night-time wind roses for the period 2023 as obtained from the on-site meteorological data